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The Navy Clothing & Textile Research Facility (NCTRF) conducted an engineering evaluation of representative Navy vessels to determine the cost of outfitting these ships with microclimate cooling systems (MCS). Using results from a previous shipboard evaluation of the feasibility of MCS use onboard ship and a recommendation by the Commander in Chief, Atlantic Fleet (CINCLANTFLT), we based this survey on only two commercially available MCS. One MCS was a simple, portable, battery-operated, water-ice cooling vest (ILC Ice Vest); the other was a tethered air-cooled system (ENCON Vortex System). Data collected from the ships included: location of hot spaces, number and type of personnel located in the space (that is, number of stationary and mobile watch personnel), duration of the shifts within the space, availability of compressed air, and type and location of power outlets. Based upon collected data, cost estimates to outfit each class of ship with MCS were generated for three different scenarios: (1) total outfitting of personnel in all hot shipboard spaces; (2) outfitting only engineering personnel; and (3) outfitting the ship for (cont'd.)

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BLOCK 19. ABSTRACT

emergency use only (e.g., repairs of boilers and steam leaks). The total cost represented the cost for the cooling systems and related components, as well as for supplemental equipment, such as freezers and air compressors, which would be required to support the MCS onboard ship. (U)

Based on the class of the ship, the total costs ranged from about $40,000 to $224,000 for complete outfitting of all hot shipboard spaces during normal operations. The cost to outfit only the engineering spaces ranged from about $32,500 to $182,000 during normal operations. The least costly method, that is, to outfit for emergency use only, costs from $1,500 to $10,000 if no additional ice-making capabilities are required. If ice machines are necessary to support the emergency systems, $8,300 should be added to the estimates. (U)

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

FIGURE PAGE

LIST OF ILLUSTRATIONS (CONTINUED)

FIGURE PAGE

LIST OF TABLES

INTRODUCTION

Navy Clothing and Textile Research Facility (NCTRF) was tasked by the Commander-in-Chief, Atlantic Fleet (CINCLANTFLT) to conduct an engineering evaluation of representative Navy vessels to determine the cost of outfitting these ships with microclimate cooling systems (MCS). A previous evaluation performed by NCTRF for CINCLANTFLT indicated that the concept of MCS onboard ship was very feasible (1). Because shipboard personnel overwhelmingly preferred a simple, portable, battery-operated, water-ice cooling vest (ILC Ice Vest), we conducted this engineering evaluation in light of outfitting these ships - all of which have had previous heat stress problems - with this particular MCS. However, CINCLANTFLT felt that a tethered air cooled system (ENCON Vortex System) may be useful for some watchstanding duties in which the individual is very stationary. We therefore also estimated the cost of outfitting stationary watch personnel with a tethered air MCS.

For this engineering evaluation, the data we collected from the ships included: location of hot spaces, number and type of personnel located in the space (that is, number of stationary and mobile watch personnel), duration of the shifts within the space, availability of compressed air, and type and location of power outlets. The data were then reduced to provide cost estimates of outfitting each class of ship with MCS for three different scenarios - total outfitting of personnel in all hot shipboard spaces, outfitting only engineering personnel; and outfitting the ship for emergency use only (e.g., repairs of boilers, steam leaks, etc.). The total cost represented the cost for the cooling systems and related components, as well as for supplemental equipment, such as freezers and air compressors, which would be required to support the MCS's onboard ship. Based on the class of the ship, the total costs ranged from approximately $40,000 to $224,000

for complete outfitting of all hot shipboard spaces during normal operations. The cost to outfit only the engineering spaces ranged from approximately $32,500 to $182,000. The least-costly method - that is, to outfit for emergency use only - costs between $1,500 to $10,000 if no additional ice source is needed.

This report provides some background as to the use of MCS onboard ship and details the methodology and results of the shipboard survey. Recommendations for utilization of the cooling systems onboard ship are also included.

BACKGROUND

Heat stress is a severe problem on older, steam-driven vessels and is responsible for limiting work times, reducing work performance, and jeopardizing personnel safety. One method of alleviating heat stress is through the use of personal cooling systems which condition the environment in immediate contact witn the individual. To investigate the feasibility of using microclimate cooling systems onboard ship, CINCLANTFLT tasked NCTRF to conduct an evaluation on hot-designated Navy ships. The study was intended as a subjective and objective evaluation of the concept of using MCS to relieve heat stress, increase work times, and improve personnel morale in engine spaces and in other hot spots aboard the ship.

Two cooling concepts, air and liquid, were evaluated aboard the USS Lexington in March-April 1987 (1). Data gathered during this study included physiological measurements, performance assessment, and subjective comments gathered through questionnaires and verbal debriefings. We also evaluated the extent of logistic support required to maintain the cooling systems. The main conclusion of the evaluation indicated that MCS was strongly favored, with the portable, battery-operated water-ice vest (ILC Ice Vest) the preferred system. The air concept (Encon Vortex), although extremely effective and low-cost, was not well-received The

overwhelming complaint for the air vortex system was the need to be tethered to a compressed air line. (There are no suitable commercially available portable air systems.) The sailors did not like the limitation on mobility imposed by the tethered cord, and even individuals who were quite stationary on their watch did not prefer the air vest concept.

Based on the results of the shipboard study of MCS and laboratory evaluations that demonstrated the effectiveness of MCS's in reducing heat stress (2,3), CINCLANTFLT wanted to determine the cost of outfitting representative Navy vessels with MCS's. Even though the tethered air system was not favorably received, CINCLANTFLT felt that it may be useful for some shipboard applications. The system is effective, low-cost, provides excellent cooling and, after the initial setup, requires little logistic support. This system should be quite rugged for individuals who are stationary. A better method for handling the tether cord may make the system much more attractive to shipboard personnel.

A survey was conducted by CINCLANTFLT to identify which ships, and which spaces onboard these ships, have a significant heat stress problem.

For this report, the following ships have been identified and served as models for their class of ships:

1. Aircraft Carrier:	CV-43	USS Coral Sea
2. Aircraft Carrier:	AVT-16	USS Lexington
3. Destroyer:	DDG-2	USS Lawrence
4 Amphibious Ship:	LPD-13	USS Nashville
5. Frigate:	FF-1038	USS McCloy
6. Cruiser:	CG-17	USS Yarnell

Hot spaces were identified on each ship and included all engineering spaces (fire rooms, engine rooms, generator rooms, auxiliary rooms, pump rooms), the scullery, the galley, the bake shop, the laundry and press rooms.

There are several approaches to outfitting ships with MCS. The most comprehensive and most expensive approach is to outfit each person working in each hot space with his/her own MCS. The second approach would be to outfit only engineering space personnel with MCS. The third and least comprehensive approach is to provide each ship, based upon class, with a fixed number of MCS, for emergency repair work in hot spaces. For this report, we generated data to support each of these three possible scenarios under two possible conditions: Normal Operations and General Quarters. A spectrum of cost estimates, depending upon each ship's unique needs and/or wants, could therefore be generated.

DESCRIPTION OF COOLING SYSTEMS

The two cooling systems considered in this evaluation are commercially available. One is a portable circulating liquid system and the other a tethered air circulating system. The Model 1905 Cool Vest is manufactured by ILC Dover, Inc., of Frederica, DE. It includes a torso vest made of heat-sealed, polyurethane-coated nylon with an inner bladder that allows liquid to flow through. Its backpack contains an 8-volt, rechargeable gel-cell battery (which lasts two hours under normal usage) and pump/motor assembly. The backpack also contains a resealable plastic bag which is filled with water (the circulating liquid) and ice (the cooling medium). The manufacturer recommends 4-8 pounds of ice. In our shipboard evaluation, we used 6 lbs. of ice so that replenishment was needed only every 2 hours. We therefore based our cost estimate on this utilization rate. The total weight of the system with 6 lbs. of ice was 13.5 pounds.

The Encon Air Vortex System, Model 02-6360, consists of an air vest connected to a vortex tube. It is manufactured by Encon Corporation, Houston, TX. The vest comes in two sizes, regular and extra large, and is constructed of a Buna-N-coated nylon shell with a perforated interior and an inner air distribution system for both the front and rear of the vest. High pressure air enters a vortex to be separated. The cold air from the vortex tube is fed into

the vest, while the warm air is directed away from the user. The temperature and flow rate of the air into the vest can be controlled using the control valve located on the vortex tube. The system is powered by a compressed air line. The manufacturer recommends anywhere from 80-100 psig @ 20 scfm.

METHODS

The original representative list of ships identified in the BACKGROUND was followed. With the exception of the USS Nashville, we personally visited the ships to gather and/or verify information. Data from the USS Nashville were obtained from a previous study conducted by Life Support Systems, Inc.(4).

Each ship was provided a series of standard forms (Figure 1) on which to graph the respective work space and to show the equipment layout for each room. For each identified "hot spot", the following information was requested from the ship:

a. Room location and dimensions.
b. Normal operating ambient conditions in the space, including temperature and humidity.
c. Normal manning of the space, including location and number of fixed and mobile watches.
d. Availability of electricity and compressed air lines within the space.
e. Number of watch stations per day.
f. Any additional comments.

The information obtained from the ship's personnel was graphed and tabulated. Calculations regarding the number of MCS's required for the three scenarios under Normal Operations and General Quarters and the costs for purchasing and logistically supporting the

cooling systems were then made. (Normal operations are the normal every day manning requirements. General Quarters are the emergency or alert operating conditions when manning in the engineering spaces increase.)

The total number of required systems was determined through evaluation of the graphical depiction of the spaces returned to us by the ships and verified by personal visits. Each stationary (fixed) watchstander was issued an air vest; each mobile watchstander was issued a portable ice vest. Except for emergency use only, all scenarios assumed that each watchstander was issued his/her own MCS. This was the result of discussions with CINCLANTFLT and ships' personnel who were concerned about cleanliness and hygiene of MCS that were shared among individuals.

Support equipment for the Encon Air Vest included regulators and filters, which could support up to three vests at a time. For the ice vest, battery/charger systems were necessary to operate the vest. The RESULTS section details the rationale for what comprised a system for different classes of ships. In addition, because we were advised that available freezer capacity onboard ship is limited, we estimated the number of ice machines required to support the total number of portable ice vests for each ship. The costs for outfitting the ship for the three scenarios was determined by multiplying the unit cost for each component by the total number of required components.

RESULTS

Figures 2 through 6 depict representative hot spaces from the classes of ships outlined in the BACKGROUND. (As data from the USS Nashville were previously presented (4), no graphics are provided for this ship.) The location of the ship's personnel (fixed or mobile) and major equipment are plotted in graphic form. The low-pressure compressed-air availability is

indicated as "LP Air". The location of the 440 VAC in or around the hot spaces could not be shown on the graphs because of its location outside the immediate work space. Because of the similarity of spaces, not all identified hot spaces were graphed. For example the USS Coral Sea provided graphics for Engine Room #1 only, implying that Engine Rooms 2,3, and 4 are arranged and manned in a similar fashion. Only Fire Room 1A was graphed, implying that the 11 other fire rooms are similar. Unique spaces - such as the bake shop, laundry, scullery and galley -were all individually graphed. We were not able to represent the lower level of the engine room of the USS Yarnell because the ship was being refurbished at the time of our visit and our ship's contact felt that, since there was no manning in the lower level, the graphics of the upper level would suffice.

Tables 1 through 6 present the tabulated data for each ship. The hot spaces were separated into engineering and other spaces. For each ship, three separate tables are presented - one for a general description of the space, one for the air vest requirements, and one for the ice vest requirements. Part A of the Tables describes the environmental conditions within the space and the availability of electricity and 100 psi air supply. We were not able to get information concerning the specific capacity size of each ship's air compressor. As described by USS Yarnell personnel and noted in Table 6a, air supply may be prioritized under emergency situations in which the air system would be shunted to operating engineering controls only.

Part B in the Tables represents tabulated data for the fixed watch air vest requirements and cost. "Fixed Watch" refers to the number of personnel requiring a stationary system in the work space. "Shifts" refers to the number of rotations of workers manning a watch station. Normally, there are two or three shifts per work space. A two-shift watch station mans the work space in two, twelve-hour or four, six-hour shifts. For the six-hour watches, watchstanders return to duty every 12 hours. A three-shift work station mans the work space

in three, eight-hour or six, four-hour shifts. For the four-hour watches, workers return to their watch station every 12 hours. Therefore, for a two-shift watch station, only two groups of workers stand watch throughout the day; for the three-shift stations, three groups are rotated over 24 hours. The number of "Air Vests & Hoses" for any hot space is calculated as the product of "Fixed Watch" x "Shifts". The summation of these numbers for all hot spaces provides the total number of air vests needed to outfit all stationary personnel. Regulators and filters are provided to support no more than three air vests at one time. Therefore, the required number of "Regulators and Filters" for each space would equal the "Fixed Watch" divided by 3 and rounded up to the next higher number.

Using unit cost values from Table 7, total cost estimates have been determined for both Normal and General Quarters (GQ) operations for Engineering, Other (non-engineering) spaces, and Complete Outfitting. For outfitting during normal operations, the total number of required vests and support equipment is the sum of the columns "Air Vests & Hoses" and "Regulators and Filters", respectively. For the Complete Outfitting during normal operations, the required number of vests and support equipment is the sum of "Total Engineering" and "Total Other." As noted above, during GQ all personnel assigned to a particular space will be on duty at the same time. However, all of these people may not be at their assigned duty stations, but may be rotated to elsewhere on the ship (e.g. to damage control teams). As discussed with the Fleet Maintenance Officer at CINCLANTFLT (5), during GQ manning in the engineering spaces will probably double. We therefore used the estimate of 2 times the normal watchstanders to calculate the requirements for GQ. Since we have already assumed that all personnel will be issued their own air vest, GQ will not affect the number of "Air Vests & Hoses." (For simplicity, we have assumed that each person will also be issued his/her own hose, even though this may not be necessary during normal operations.) The amount of support equipment, however, may have to be increased when MCS usage is increased. For example, according to Table 1b, during GQ there

will be 2 watchstanders in each of the Generator rooms where only 1 had been during normal operations. However, since each regulator and filter will support up to three air vests, the number of required support equipment will not increase in these spaces. In the Firerooms, there are normally three watchstanders who can be supported with one regulator and filter. During GQ, there will be 6 watchstanders, who will now require 2 regulators and filters to support their air vests. Manning in the "Other" spaces does not change during GQ; therefore, there are no additional costs to consider.

Costs for the vests and hoses were calculated by multiplying the unit costs found in Table 7 for the vest, vortex, belt, and hose ($452.00) by the number of "Air Vests & Hoses." For the support equipment, the sum of the number of "Regulators and Filters" was multiplied by the unit cost for these components ($120).

Part C of the Tables provides data for mobile personnel who would wear the ice vest. "Mobile Watch" refers to the number of personnel who move around the space and would require a portable system in the work space. As discussed above, "Shifts" refer to the number of rotations of workers manning a space. The number of "Ice Vests" for any hot space is calculated as the product of: "Mobile Watch" and "Shifts." The summation of "Ice Vests" provides the number of ice vests needed to outfit all personnel requiring a portable MCS in the hot spaces. "Ice Machines" is the number of ice machines required to support the total number of ice vests expected to be operating in each scenario. The number of ice machines was determined on the basis of each ice machine's producing 1500 pounds of ice per 24 hours and each ice vest using six pounds of ice every two hours, as described in the BACKGROUND. In twenty four hours, a single ice vest can consume seventy two pounds of ice (6 lbs/2 hrs X 24 hrs/day); therefore, a minimum of twenty ice vests can be supported full-time by each ice machine. "Battery & Charging Systems" refers to the number of batteries and chargers required to operate an ice

vest. This number is also dependent upon the number of shifts at a particular watch station and whether we are calculating for normal or GQ operations. Based on the manufacturer's specifications, each battery lasts 2 hours and can be fully recharged in 8 hours. For calculation purposes, we assumed that the sailor will pick up the required number of batteries for his/her shift prior to reporting to the duty station. Batteries will only be recharged at the end of the rotation. For the 2, 12-hour watches, 6 batteries and 6 chargers would be needed per station. For the 2, 6-hour watches, 6 batteries and 3 chargers would be required. For the 3, 4-hour shifts, 4 batteries and 2 chargers are needed. For the 3, 8-hour shifts, 4 batteries and 4 chargers are required. Because we did not know the specific information about the hourly cycles of the watches, we averaged the requirements for each of the 2 and 3-shift possibilities. Therefore, for spaces with two shifts, we assumed that 6 batteries and 4 chargers would be required to support each mobile watch during normal operations. For spaces with three shifts, 4 batteries and 3 chargers would be necessary for each ice vest. During GQ when we have assumed that manning in the engine spaces will double, personnel may be expected to stand watch for 24 hours. To outfit for GQ purposes, therefore, we will provide a system with 12 batteries and 6 chargers for both 2 and 3-shift ships.

Using the unit cost figures in Table 7, we calculated the cost of outfitting these representative ships with portable MCS. Total costs were determined for both normal and GQ operations for outfitting the Engineering spaces only and for a Complete Outfitting.

Table 8 provides an Outfitting Cost Summary by class of ship. In this Table, we describe three scenarios for providing shipboard MCS, namely, Emergency Use Only, Engineering Use Only, and Complete Outfitting of hot spaces (engineering and other hot spaces combined) for both Normal Operations and General Quarters Operations. We defined an emergency use system as one in which the cooling vests would be available to any ship's personnel in case of extreme

hot conditions. For the emergency scenario, we considered only the portable, liquid-cooled system because, according to CINCLANTFLT, in case of repairs, steam leaks, etc., the individual would require mobility throughout the space.

The determination of Emergency Use Only requirements was made by counting the number of hot spaces reported for each ship and then estimating what percentage of these spaces will need personal cooling at any one time. Realizing the continuous upkeep of the ships, we decided to take an overly cautious estimate and assumed that 25% of the hot work spaces could require emergency repairs at the same time. We then assumed that if an emergency repair was needed, two sailors may be required to perform the duty. Using this rationale, the USS Coral Sea would need to support 14 ice vests (28 hot spaces X .25 x 2 vests /space), the USS Lexington would need 5 ice vests, the USS Lawrence would need 3 ice vests, the USS Nashville would need 2 ice vests, the USS McCloy would need 4 ice vests, and the USS Yarnell would need 3 ice vests. Since, as previously noted, a single ice machine can support 20 ice vests utilized continuously, each ship can be supported by a single ice machine for the Emergency Use Only requirements. Of course, with so few ice vests, an additional source of ice may not be required. The ship may be able to support the vests with its current ice machines. For each vest, 5 batteries and 5 chargers should be provided to support continuous usage. Therefore the Emergency Use Only requirements can be determined by multiplying the number of vests required by $720.00 ($220 for the vest and $500 for battery/charging system) and adding the $8,300 for the ice machine. Therefore the cost to provide Emergency Use Only support for the USS Coral Sea is $18,380, the cost for the USS Lexington is $11,900 , the cost for the USS Mc Cloy is $11,180, the cost for the USS Lawrence and the USS Yarnell is $10,460, and the cost for the USS Nashville is $9,740. With no additional ice machine, the costs would range from $1,440 for the USS Nashville to $10,080 for the USS Coral Sea.

We determined the additional air flow requirements on existing shipboard low pressure air compressors (LPAC) when the air-cooled MCS are used minimally and maximally. Outfitting only engineering personnel during normal operations was considered the minimum supplemental demand on the LPAC. Outfitting the complete ship during GQ was considered the maximum supplemental demand on the LPAC. These data, which are presented in Table 9, were calculated by multiplying the number of air vests found in Tables 1b - 6b by the recommended air flow (20 scfm) for each vest. Because of the number of watchstanders, the greatest demand on the LPAC was found on the USS Coral Sea, with a minimum air flow requirement of 960 standard cubic feet per minute (scfm) and a maximum air flow requirement of 2,040 scfm. The USS Lexington has the second largest additional LPAC demands, with a minimum of 740 scfm and a maximum of 1,580 scfm. The USS Lawrence may have additional LPAC demands of between 240 scfm and 520 scfm; the USS Nashville of between 280 scfm and 560 scfm; the USS McCloy of between 320 scfm and 660 scfm; and the USS Yarnell of between 200 scfm and 400 scfm. We were not able to obtain information regarding the capacity of any of the ships' current LPAC. We are presenting these data so that the ship's personnel can determine whether additional air compressors may be needed to meet the demand for Microclimate cooling.

DISCUSSION

The summary of data from the ships involved in this survey demonstrates that MCS's can be installed onboard Navy vessels at a relatively low cost. For the larger of the "hot" carriers, such as the USS Coral Sea, the cost to completely outfit the vessel with air- and liquid-cooled MCS's ranges from $224,000 under Normal Operations to $336,392 for General Quarters operations.

To permit flexibility in outfitting each of the particular ships, we estimated these costs on the high side. For example, we provided each sailor with his/her own cooling vest, including

battery/charger systems where necessary. We also assumed that cooling will be required continuously for 24 hours. Further, we outfitted each watchstanding location in every hot space identified on the ship. We therefore built in options to permit ships to cut costs and to customize a MCS outfitting for their particular needs. For example, a particular ship may determine that cooling will not be necessary for the entire 24 hours; the number of required cooling systems can therefore be adjusted as necessary. They may further decide that providing each watch station, rather than each watchstander, with a cooling system may be more economical, feasible, and logistically easier to handle.

Further flexibility for outfitting any ship can be found in the three different scenarios for installing MCS's. A ship can determine that only the Engineering spaces should be provided with MCS. They can also decide whether they want to outfit for all operating conditions (GQ scenario), for Normal Operations, or only for Emergency Use, which is by far the least expensive of the three options.

Within each scenario, costs can also be reduced by decreasing the number of battery/chargers needed per vest. We assumed that the required number of batteries will be carried to the duty station at one time. If a sailor is permitted to leave the duty station to pick up recharged batteries and/or if the station is equipped with its own chargers, the required number can be substantially reduced.

Costs can also be reduced by evaluating the ship's current source of ice and determining if the calculated number is actually required. Because each ice machine is quite expensive ($8,300), savings can be considerable if fewer ice machines than we calculated are needed.

As is obvious, space aboard any ship is at a premium. If a ship determines it would like to

purchase MCS's, storage of the components may become a serious problem. For example, if the USS Coral Sea completely outfits for GQ operations, they would require 156 air vests, 38 regulators and filters, 206 ice vests, 2,072 batteries, 1,086 chargers, 7 ice machines, and possibly an air compressor that can support the additional 2,040 scfm of compressed air required to run the air vests! (According to CINCLANTFLT, the existing compressors should be sufficient to support the cooling systems in the aircraft carriers). These storage problems would have to be analyzed and addressed by any ship attempting to outfit with MCS's.

For the most part, the MCS's discussed in this report could not be simply purchased and then installed onboard the ship. There are numerous requirements for the Ice Vest, including the ice itself, ice machines, batteries, and chargers. Because most ships are probably not equipped to provide additional ice to support the MCS, ice machines would have to be purchased, centrally installed, and maintained. Placement of the ice machines on the ship can be determined by a number of factors, including ease of access, ease of installation, availability of electrical power and water supply. Access to the machines may have to be controlled so that a supply of ice can be continuously maintained for the Ice Vests. Because of the heat and lack of storage space within the hot spaces, it is probably not practical to locate the ice machines in these areas. Rather, it may be more useful to install these machines in a central area that could be equally accessible to personnel in engine spaces, laundry, scullery, etc. Prior to their work shift, the personnel could stop by the ice machine, fill up a container with enough ice to last for the entire shift, and then proceed to their work station. These containers can be locally purchased and can range in price from $25.00 to $50.00 depending upon size. The ice can be stored in the container for 4 to 6 hours.

Battery support for the Ice Vest may also present problems for the ships. Because of the number of batteries and chargers required for a 24-hour period, a central charging station may

have to be set up to handle the logistics of assuring completely recharged batteries for each watch. Because of both space and electrical power supply limitations, it is doubtful whether each of the individual hot spaces would be able to maintain its own bank of charged batteries. As with the ice, prior to their shift, personnel would stop by the central charging station to pick up the necessary number of batteries to last for the shift's duration. After their duty is completed, they would have to return the batteries to the charging station and assure that they are properly hooked up to the chargers. Access to this station would also have to be limited.

Although not as extensive as for the Ice Vest, the Air Vest will also require some logistical support. First, a source of clean, dry compressed air will need to be provided within the hot space. Regulators and filters will have to be attached to the compressed air source, and hoses will be needed to attach the air source to the vortex tube. Once these fixtures are in place, however, little maintenance or support should be required. The fittings should not have to be moved and would be accessible for all watchstanders within the space.

One of the more significant problems with the Air Vest is the tether cord. Unless there is some modification to the current handling of the cord, it probably will present a safety problem in terms of entanglement and/or tripping over the exposed cord. This problem may be alleviated by suspending swivel connectors from the ceiling within the spaces. Further, if multiple tap-offs could be placed within the space, personnel may feel more mobile and less restricted by the tether cord. They will be able to move around the space freely by disconnecting and connecting to the various tap-offs.

Air availability may also present a problem with the use of the Air Vest. As indicated in Tables 1a-6a, all spaces, except for the Galley and Scullery, have LPAC available. Some air lines are prioritized (for example, on the USS Yarnell) and in some conditions will provide support for

necessary engineering machinery only. In such a case, no air will be available for air vest cooling. In this situation, the wearer could either leave the cooling vest on and disconnect from the tether cord or remove the air vest completely. In either case, the sailor would be no worse off than if no cooling system at all were worn, as is the current situation aboard ship.

It is possible that the capacity of the current shipboard compressors may not be sufficient when numerous Air Vests are being utilized. Since we were not able to get information on the capacities of the existing shipboard compressors, we calculated the additional minimum and maximum air flow requirements required if MCS were installed aboard the ships (Table 9). If the Air Vest requirements exceed the capacity of the ship's existing compressors, the ship would have to determine if additional air compressors should be installed. According to CINCLANTFLT no additional compressors should be needed for the larger ships (aircraft carriers). Smaller ships, however, may require new compressors to support the MCS. The space required for this additional equipment will be a significant factor in a ship's decision to outfit with MCS.

There are power, cost and upkeep requirements for these compressors. Each compressor will have power requirements that must be met by the ship's own electrical generators. Costs have been approximated for a Flooded Rotary Screw type compressor from several Massachusetts vendors. Since this compressor can provide 5 scfm of air flow per horse power, and each vest requires 20 scfm, each vest will require 4 horse power for proper operation. Therefore, the additional compressor requirements can range from 40 to 410 horse power at a cost of approximately $160 per horse power. Therefore, costs can range from $6,400 to $65,600 to provide the necessary air compressor support. Since it is possible that these air compressors will be running continuously, the ship must also consider the maintenance of the additional equipment (the compressors).

All outfitting prices provided in this report have been for initial outfitting only. The ships must also consider replacement cost of MCS's components. Items to consider are the vests, batteries, pump assemblies, vortex tubes, hoses, regulators and filters. Replacement needs will depend on everyday usage, abuse, loss and failure of equipment. The replacement costs for the air vests are listed in Table 7. Encon Corporation of Houston, Texas was contacted for information about the life expectancy of their equipment. They stated that the air vest can easily be expected to last greater than 10 years. The vortex tube (with no moving parts) can also be expected to last greater than 10 years as long as clean dry air is provided. This can be accomplished with regular replacement of the $5.00 element in the filter regulator. Replacement intervals will depend upon the cleanliness of the air supply to the filter/regulator. The hose, regulator and connectors are expected to provide a similar life span with proper care and handling.

The replacement costs for the ice vests are also listed in Table 7. ILC Dover of Frederica, Delaware was contacted for information about the life expectancy of their equipment. They stated that the vest has been manufactured for more than 10 years, that there has been no heat seal degradation in the vests, and that it can easily be expected to last greater than 10 years. A kit for repairing small punctures in the ice vest is also available at a cost of $25. They also stated that if a vest were to be destroyed, an entire vest must be purchased for replacement because individual replacement vests without hardware are not available. In the 10 years of manufacture, ILC knows of no pump failures. However, if one were to be destroyed or fail, the replacement cost would be $125. ILC Dover and a battery manufacturer suggest yearly replacement of the rechargeable batteries and replacement of the chargers only when they fail. No life expectancy could be provided for the chargers. Depending upon class of ship, an estimate for yearly replacement of batteries ranges from $3,200 to $31,200 for Engineering Outfitting under normal operations

In determining whether the cost for MCS is warranted, the ships should keep in mind that

using MCS will increase stay times in hot shipboard spaces. During deployments in the summer and/or in hot climates in which the environmental conditions dictate that the Physiological Heat Exposure Limit (PHEL) curves will be invoked, stay times will normally be reduced and more personnel per watch station will be required to assure continuous manning of the station. Because MCS reduces heat stress, these stay times should be significantly increased. Future research at NCTRF will investigate modifications of the existing PHEL curves based on the use of MCS in hot spaces.

MCS will also diminish the likelihood of heat casualties within hot spaces. Provided the sailors are well hydrated and follow other guidelines for work in hot climates, the MCS should keep body temperatures significantly lower compared to when no MCS is worn (2, 3). Further, the cool sensation of the MCS will significantly improve the sailor's feeling of well-being and should improve worker morale in hot spaces.

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1. Janik, C.R., B.A. Avellini, and N.A. Pimental. Microclimate cooling systems: A shipboard evaluation of commercial models. Natick, MA: Navy Clothing and Textile Research Facility, 1988; Technical Report No. 163.

2. Pimental, N.A. and B.A. Avellini. Effectiveness of various microclimate cooling systems in reducing heat stress. Natick, MA: Navy Clothing and Textile Research Facility report, Oct 1987.

3. Pimental, N.A., B.A. Avellini, and C.R. Janik. Microclimate cooling systems: A physiological evaluation of two commercial systems. Natick, MA: Navy Clothing and Textile Research Facility, 1988; Technical Report No. 164.

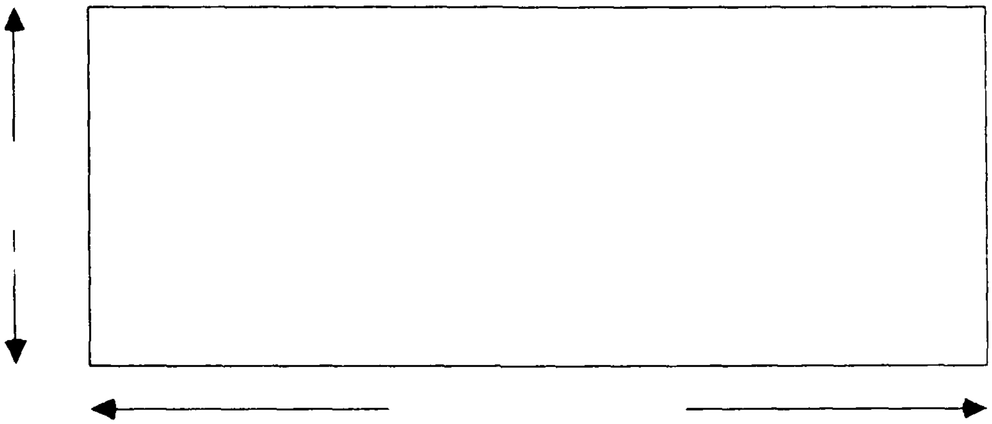
4. Life Support Systems, Inc. Final report: Engineering study to determine operational requirements and installation of microclimate systems aboard USS NASHVILLE-type ships. Contract No. N00189-87-M-AQ-26, Report No. 900420, 18 November 1986.

5. Moore, Greg, LCDR, CINCLANTFLT Fleet Maintenance Officer, Norfolk, VA Personal communication, May 1988.

LOCATION: ____________________

CONDITIONS		MANNING		FACILITIES	
Temperature:	______	Fixed Watch:	______	Electricity:	______
Humidity:	______	Mobile Watch:	______	Comp. Air:	______

WORK SPACE LAYOUT



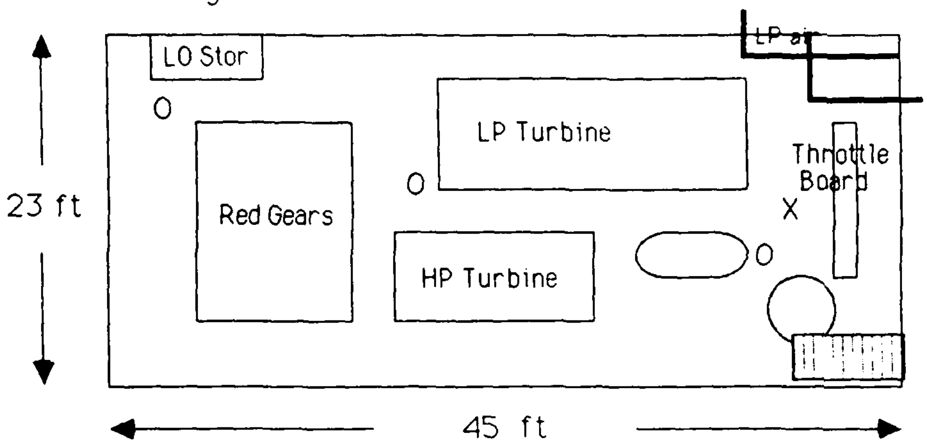
RECOMMENDATION:

______ Liquid Cooled Suits ______ Air Cooled Suits

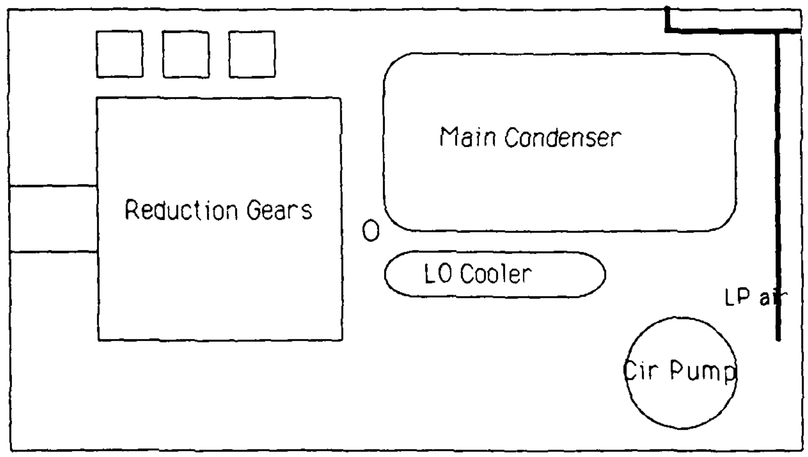
COMMENTS: ______________________________________

Figure 1. Working diagram of shipboard space.

U.S.S. Coral Sea
#1 Engine Room U/L



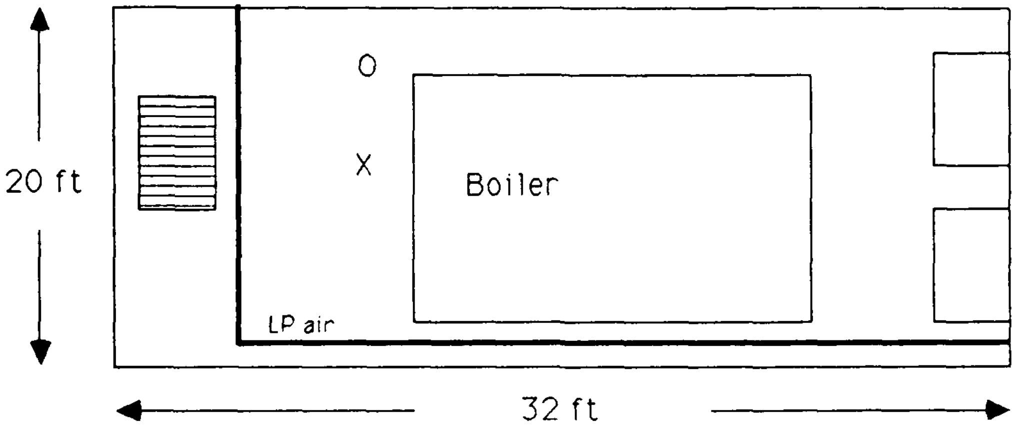
#1 Engine Room L/L



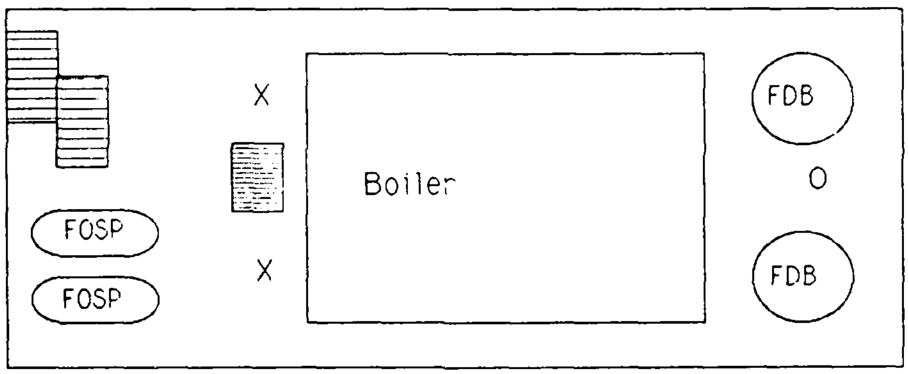
MANNING:
Fixed watch X= 1
Mobile watch O= 4

Figure 2a. Graphic depiction of upper (U/L) and lower (L/L) level of the #1 Engine Room of the U.S.S. Coral Sea.

U.S.S. Coral Sea
1A Fire Room U/L



1A Fire Room L/L

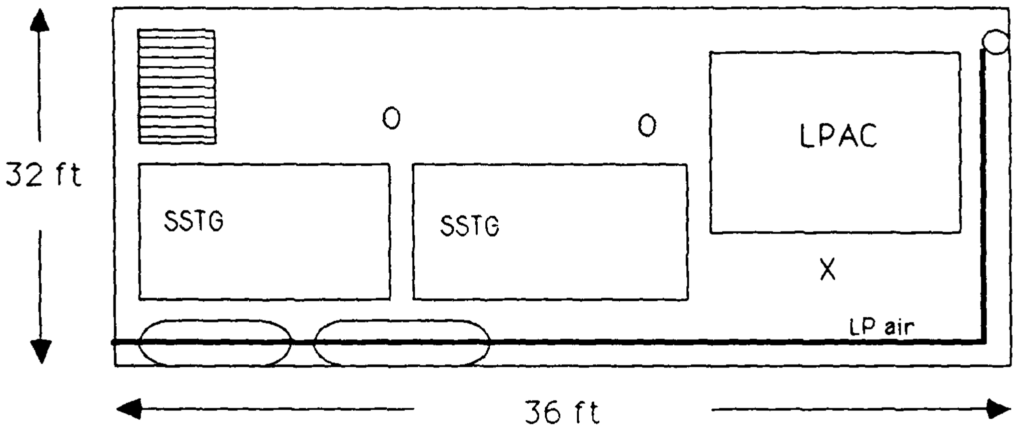


MANNING:
Fixed watch X= 3
Mobile watch O= 2

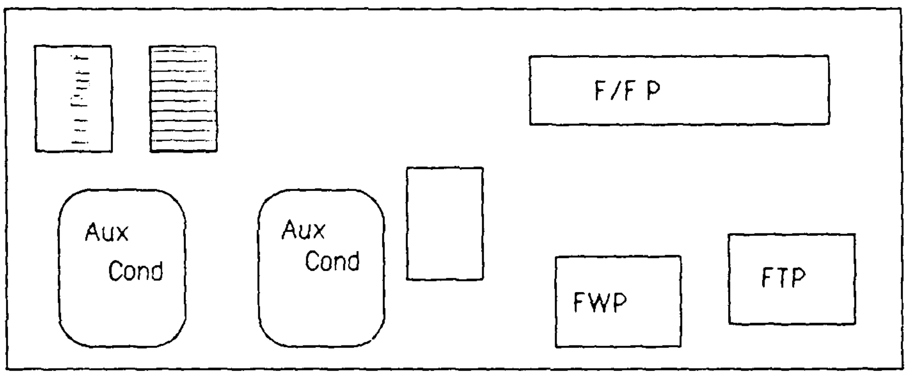
Figure 2b. Graphic depiction of upper (U/L) and lower (L/L) level of the # 1A Fire Room of the U.S.S. Coral Sea.

U.S.S. Coral Sea

#3 Generator Room U/L

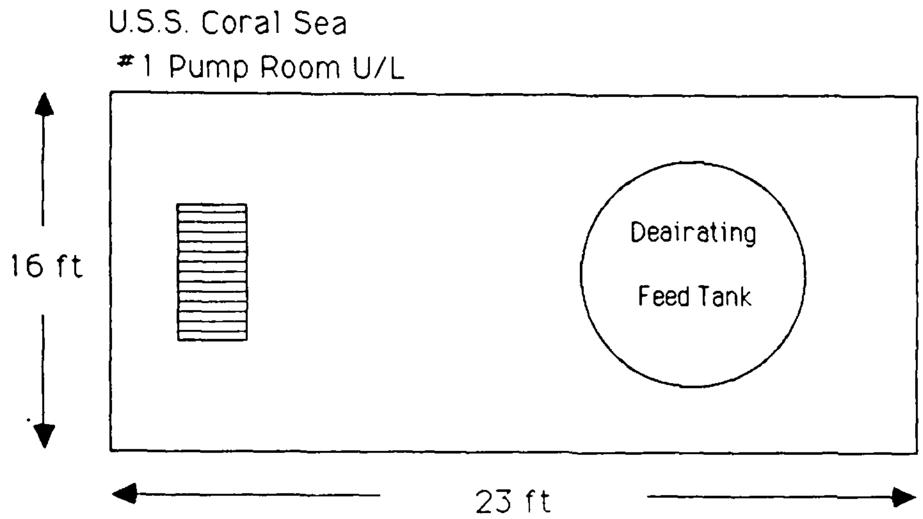


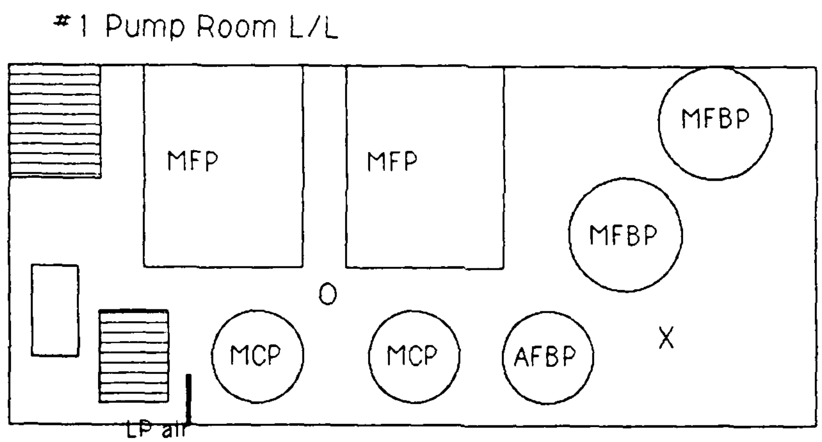
#3 Generator Room L/L



Manning:
Fixed watch X= 1
Mobile watch O= 2

Figure 2c. Graphic depiction of upper (U/L) and lower (L/L) level of the #3 Generator Room of the U.S.S. Coral Sea.





Manning:
Fixed watch X= 1
Mobile watch O= 1

Figure 2d. Graphic depiction of upper (U/L) and lower (L/L) level of the #1 Pump Room of the U.S.S. Coral Sea.

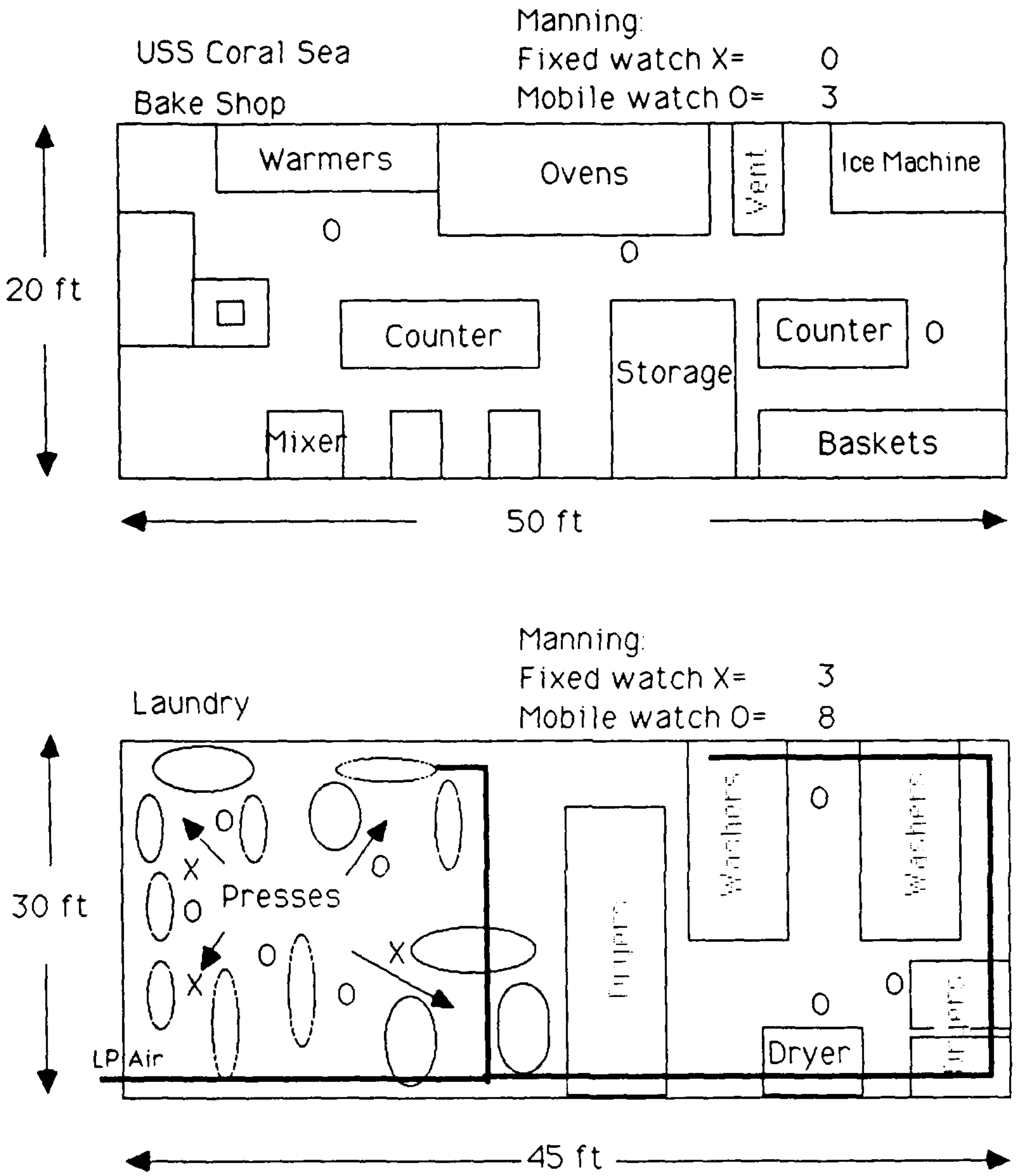
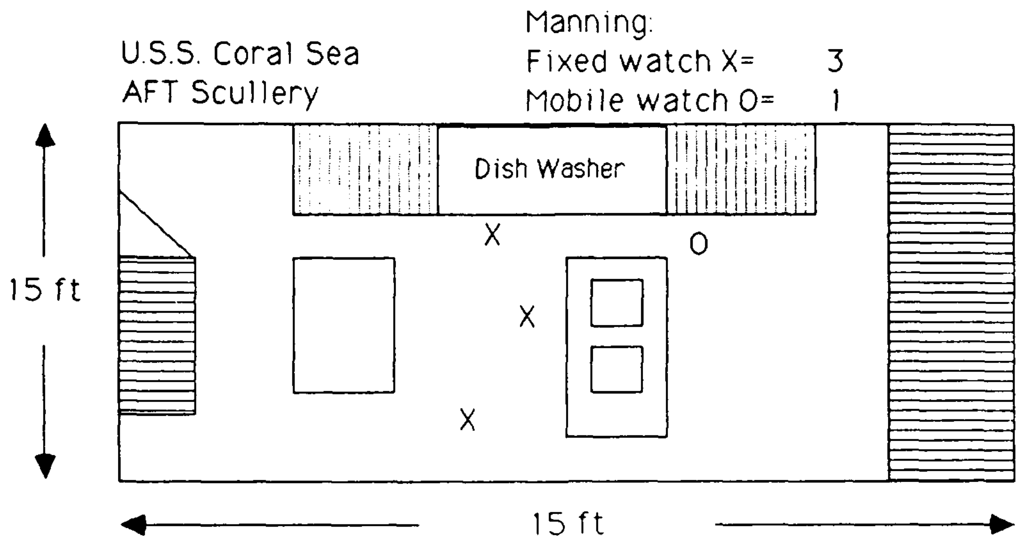


Figure 2e. Graphic depiction of the Bake Shop and the Laundry Room on the U.S.S. Coral Sea



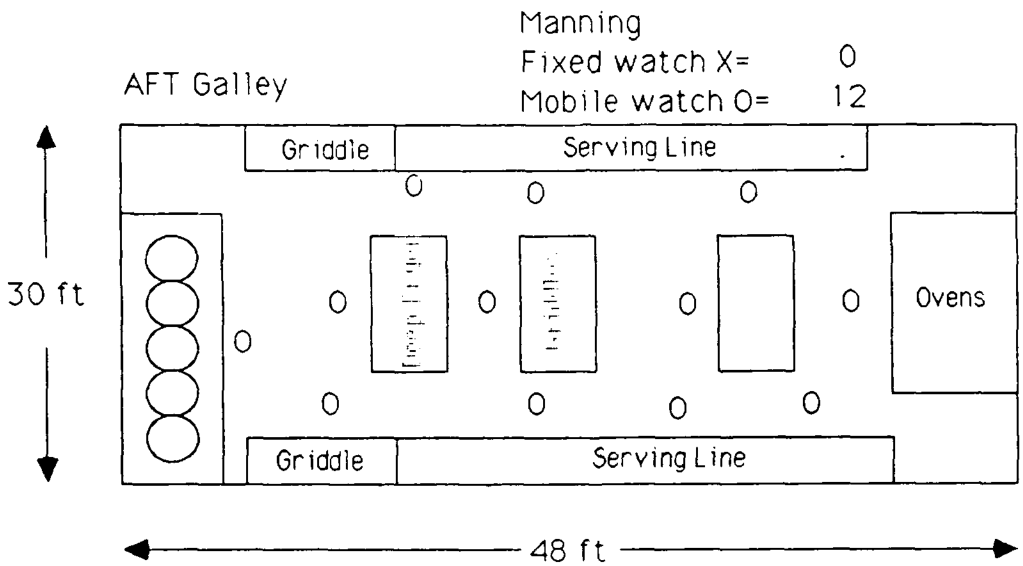
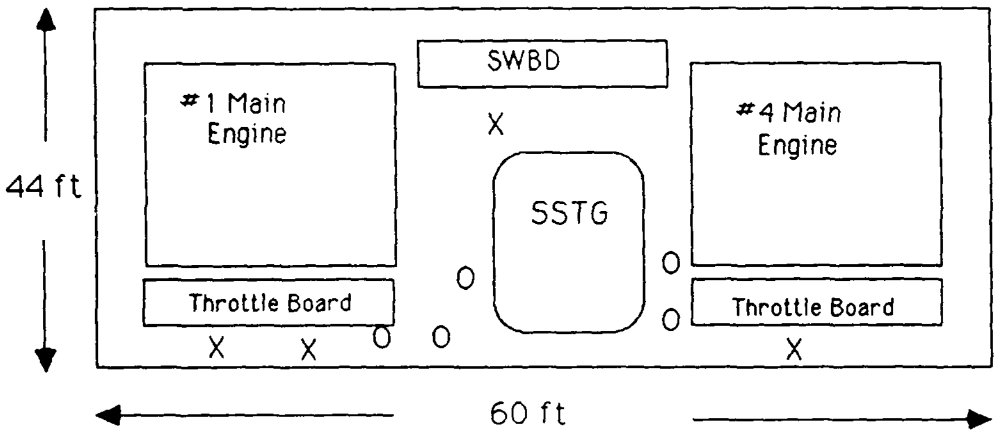
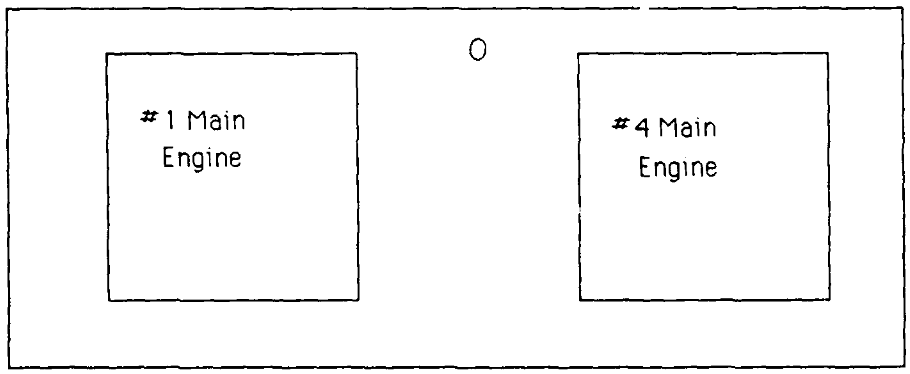


Figure 2f. Graphic depiction of the Aft Scullery and the Aft Galley on the U.S.S. Coral Sea

U.S.S. Lexington
Main Control U/L



Main Control L/L

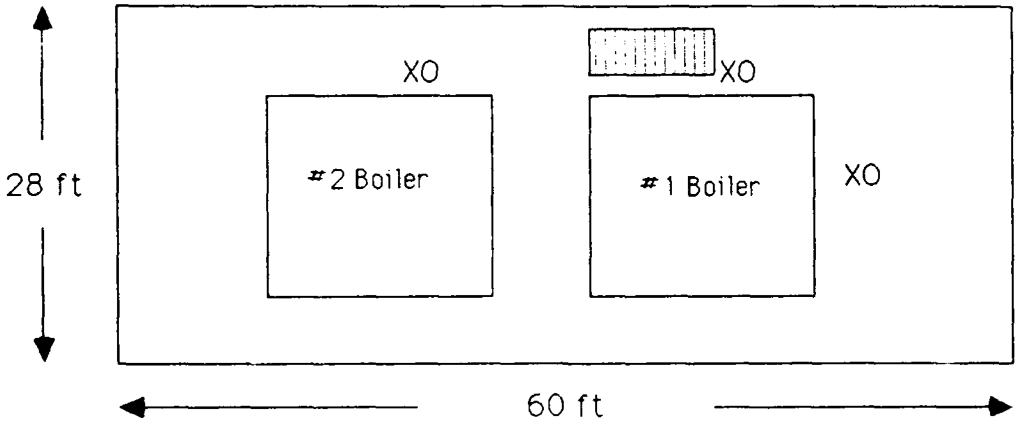


MANNING:
Fixed watch X= 4
Mobile watch O= 6

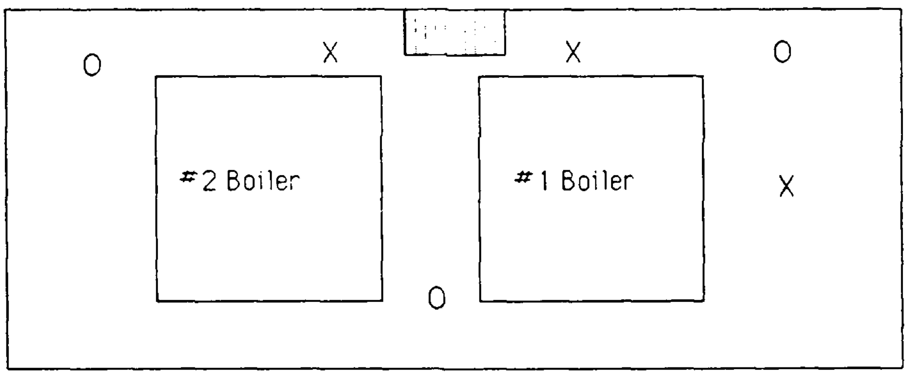
Figure 3a. Graphic depiction of upper (U/L) and lower (L/L) level of the Main Control Room of the U.S.S. Lexington.

U.S.S. Lexington

#1 Fire Room U/L



#1 Fire Room L/L

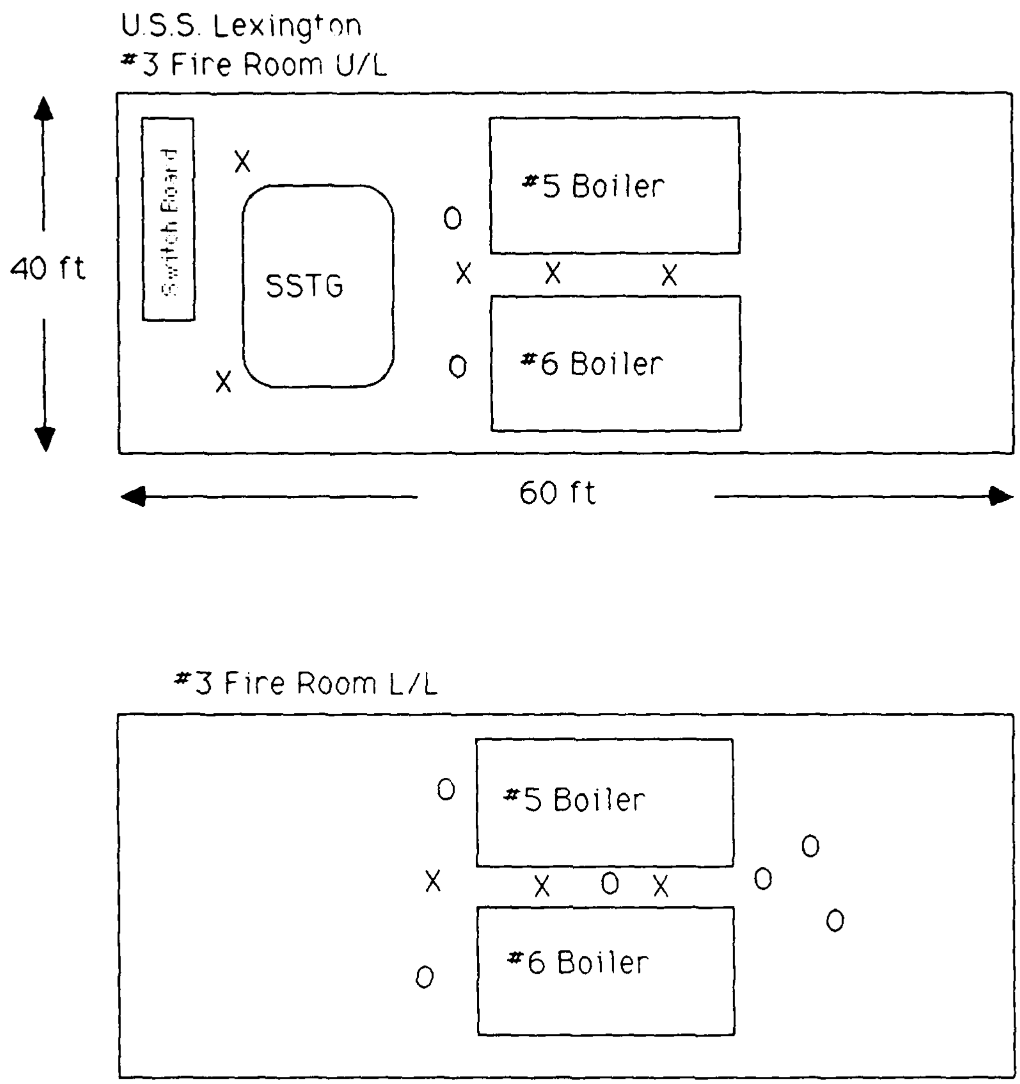


Manning:

Fixed watch X= 6

Mobile watch O= 6

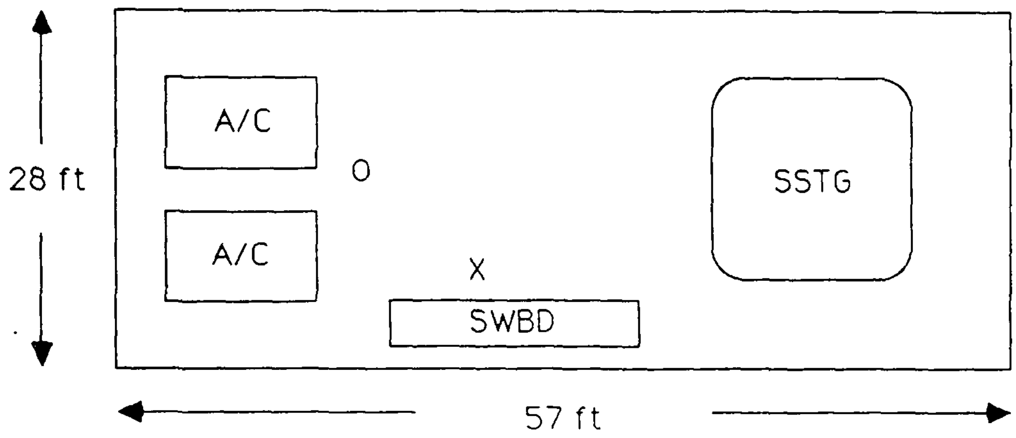
Figure 3b. Graphic depiction of upper (U/L) and lower (L/L) level of the #1 Fire Room of the U.S.S. Lexington.



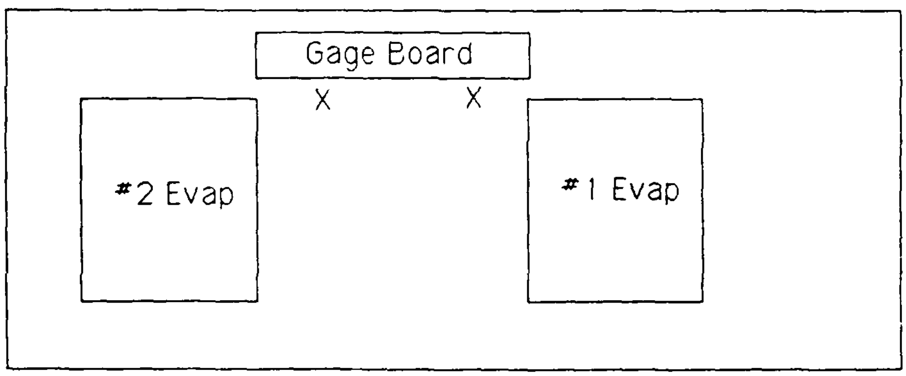
Manning:
Fixed watch X= 8
Mobile watch O= 8

Figure 3c. Graphic depiction of upper (U/L) and lower (L/L) level of the #3 Fire Room of the U.S.S. Lexington.

U.S.S. Lexington
Forward Auxiliary Room U/L



Forward Auxiliary L/L



Manning:
Fixed watch X= 3
Mobile watch O= 1

Figure 3d. Graphic depiction of upper (U/L) and lower (L/L) level of the Forward Auxiliary Room of the U.S.S. Lexington.

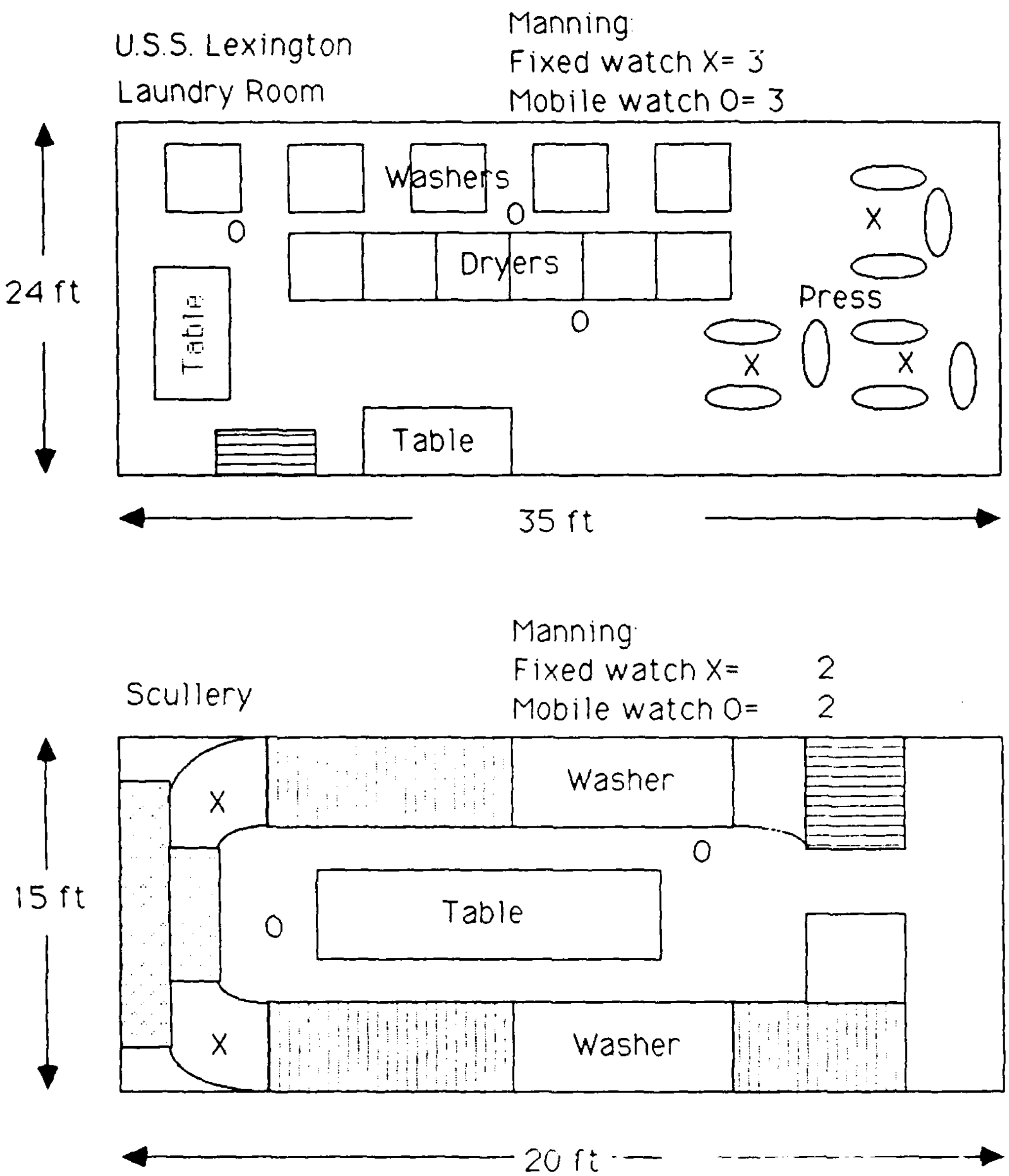
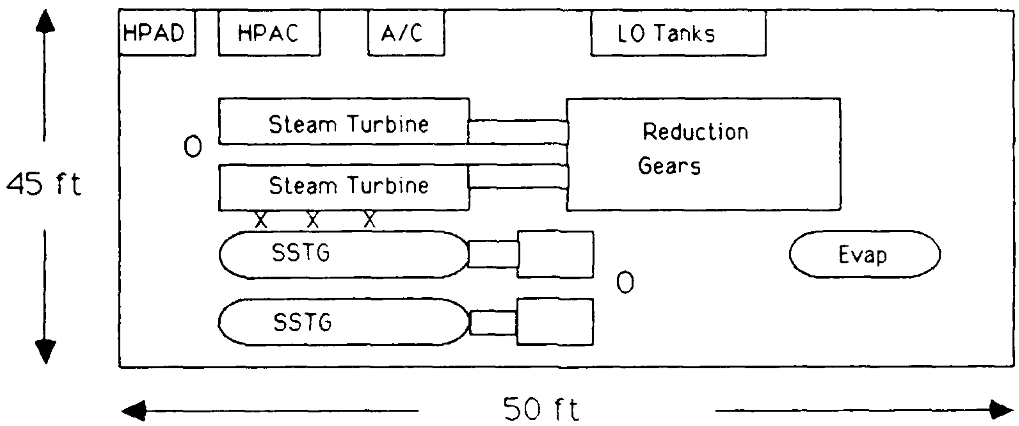
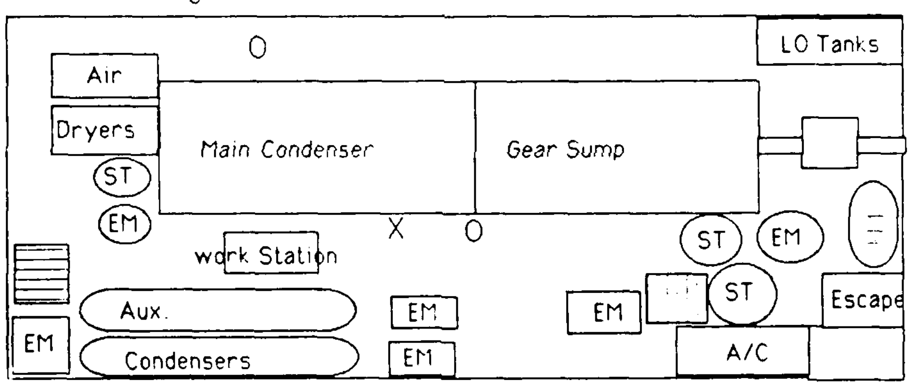


Figure 3e. Graphic depiction of the Laundry and Scullery Room of the U.S.S. Lexington.

USS Lawrence
Forward Engine Room U/L



Forward Engine Room L/L

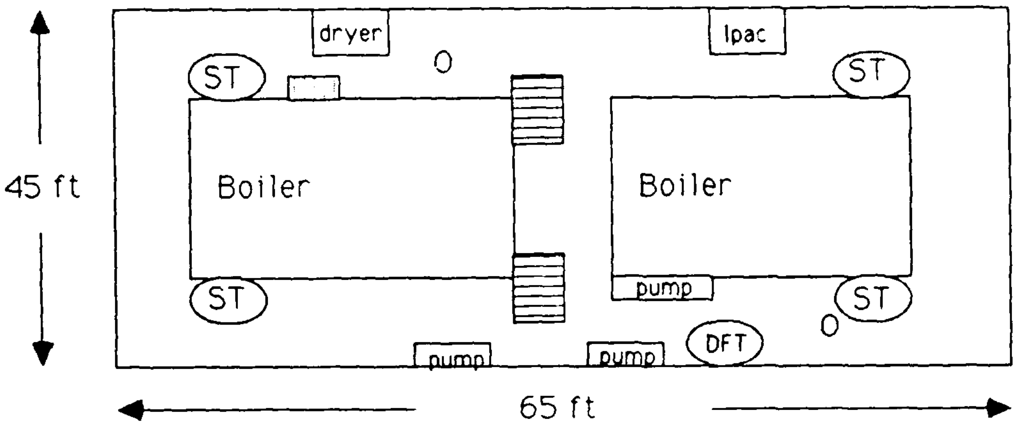


Manning:
Fixed watch X= 4
Mobile watch O= 4

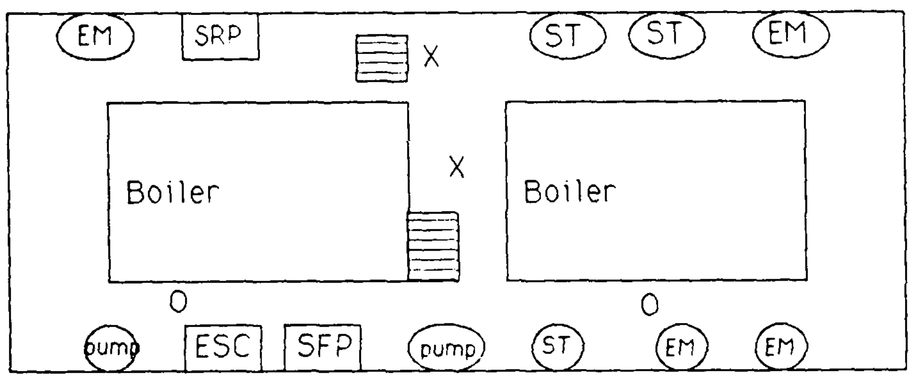
Figure 4a. Graphic depiction of upper (U/L) and lower (L/L) level of the Forward Engine Room of the U.S.S. Lawrence.

U.S.S. Lawrence

Forward Fire Room U/L



Forward Fire Room L/L



Manning:

Fixed watch X= 2

Mobile watch O= 4

Figure 4b. Graphic depiction of upper (U/L) and lower (L/L) level of the Forward Fire Room of the U.S.S. Lawrence.

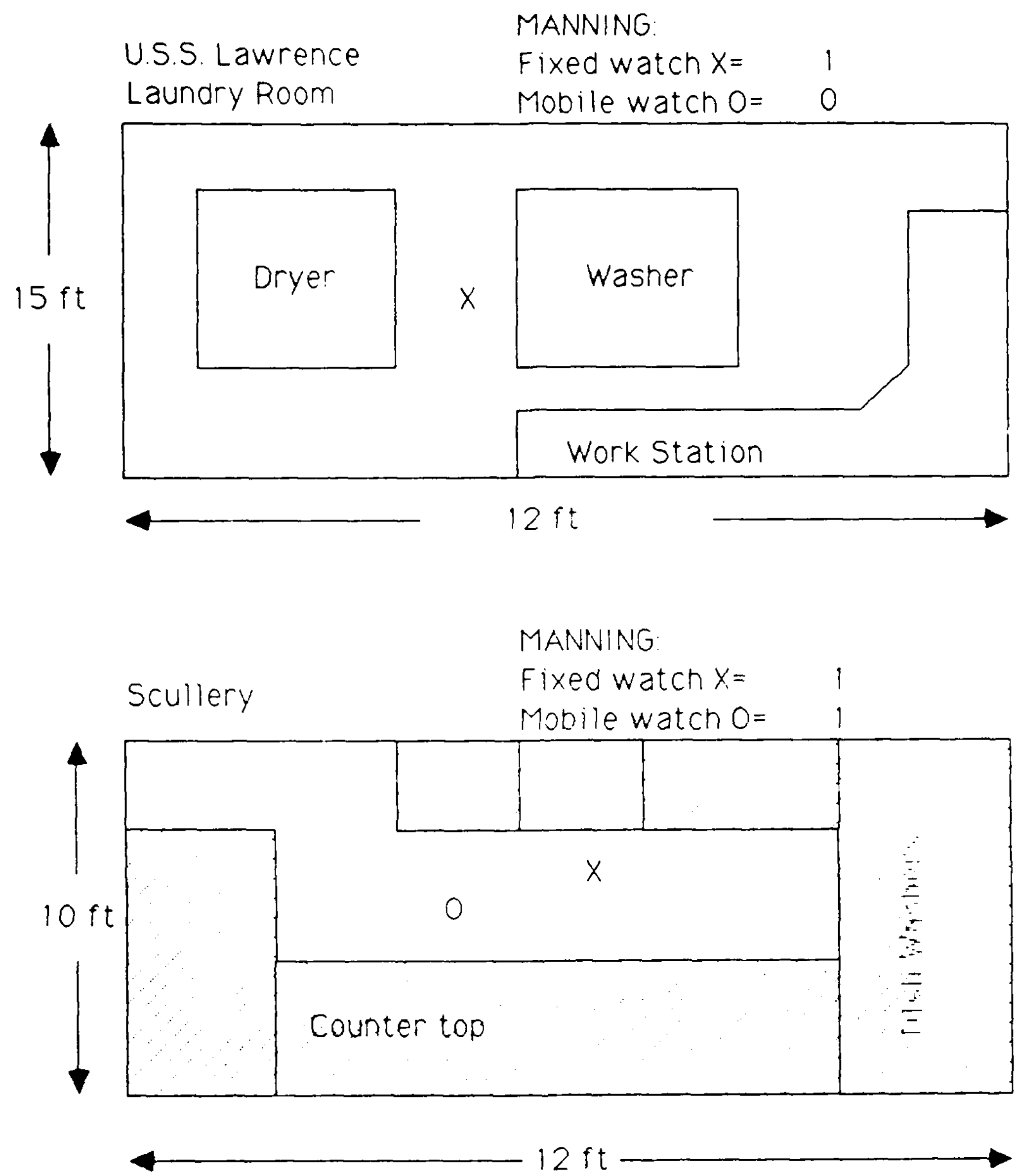
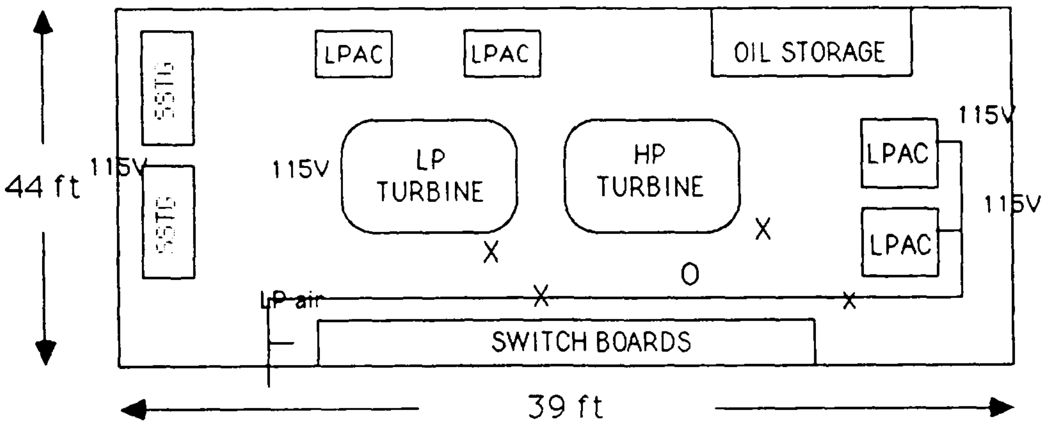
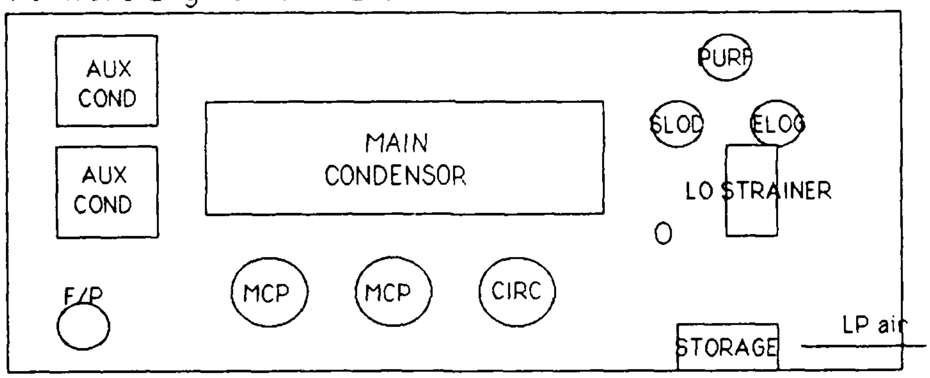


Figure 4c. Graphic depiction of the Laundry and Scullery Room of the U.S.S. Lawrence.

U.S.S. McCloy
Forward Engine Room U/L



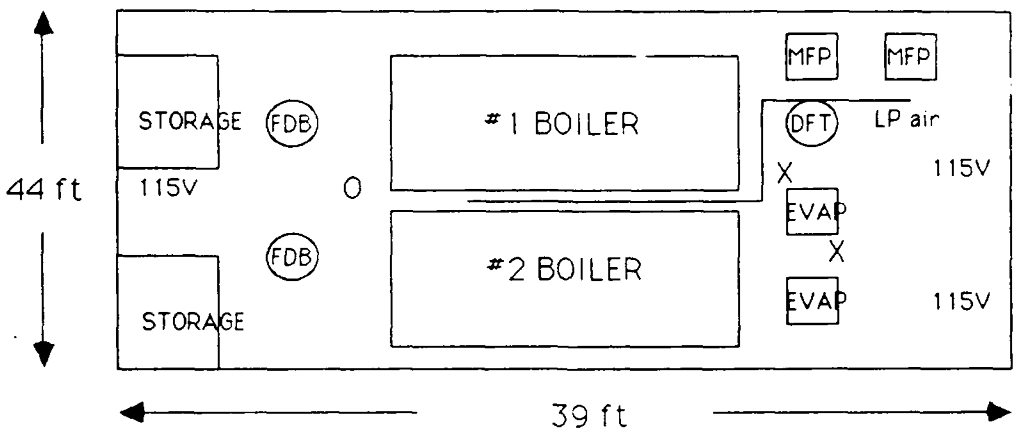
Forward Engine Room L/L



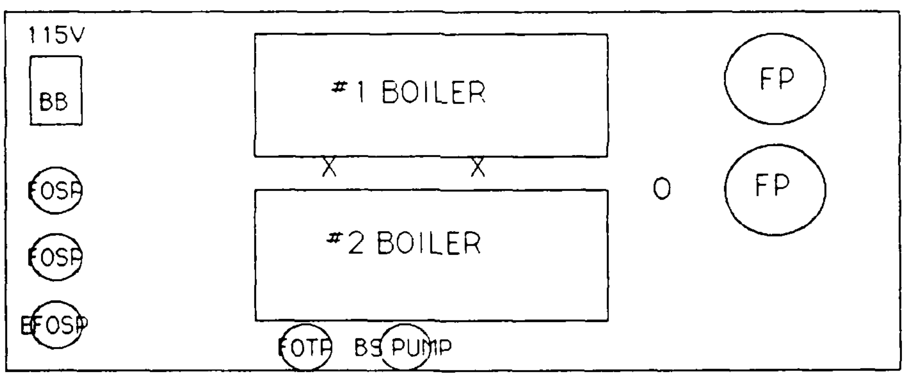
Manning:
Fixed watch X = 4
Mobile watch O = 2

Figure 5a. Graphic depiction of upper (U/L) and lower (L/L) level of the Forward Engine Room of the U.S.S. Mc Cloy.

U.S.S. McCloy
Forward Fire Room U/L

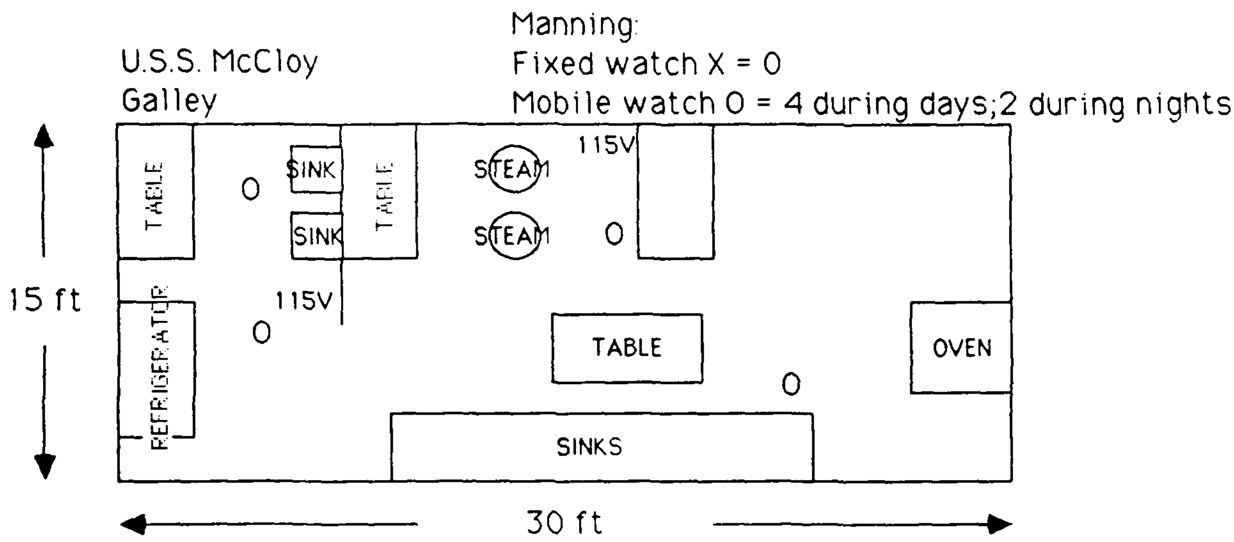


Forward Fire Room L/L



Manning:
Fixed watch X = 4
Mobile watch O = 2

Figure 5b. Graphic depiction of upper (U/L) and lower (L/L) level of the Forward Fire Room of the U.S.S. Mc Cloy.



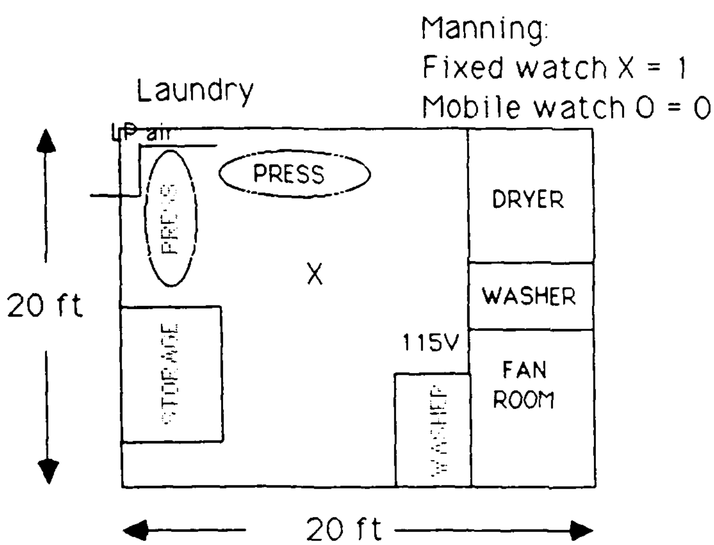


Figure 5c. Graphic depiction of the Galley and Laundry Room of the U.S.S. Mc Cloy.

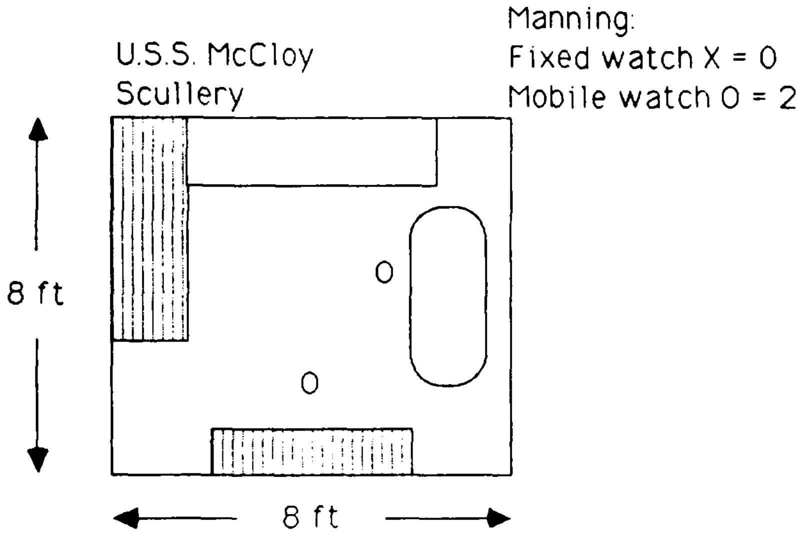
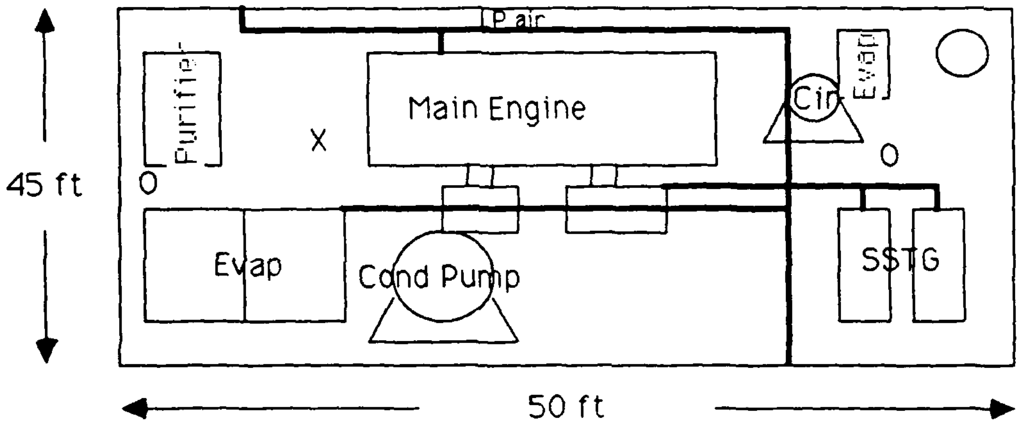


Figure 5d. Graphic depiction of the Scullery on the U.S.S. Mc Cloy.

U.S.S. Yarnell
1 Engine Room U/L

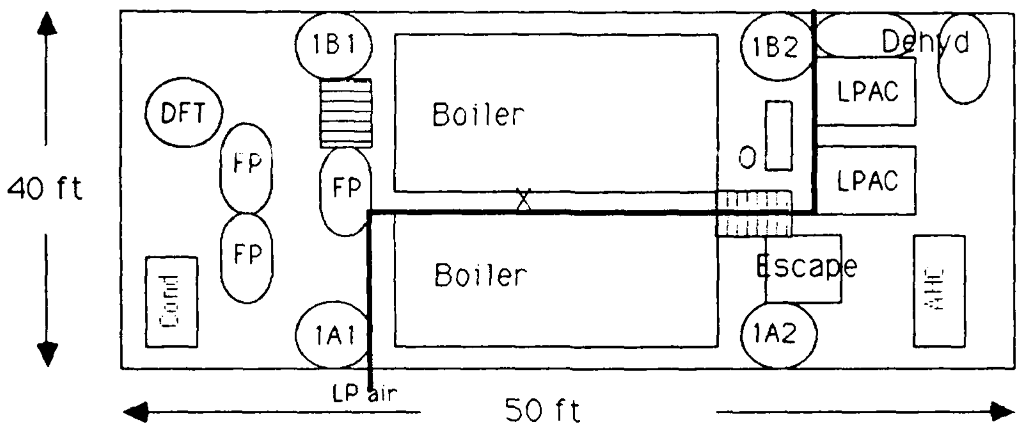


MANNING:
Fixed watch X= 1
Mobile watch O= 2

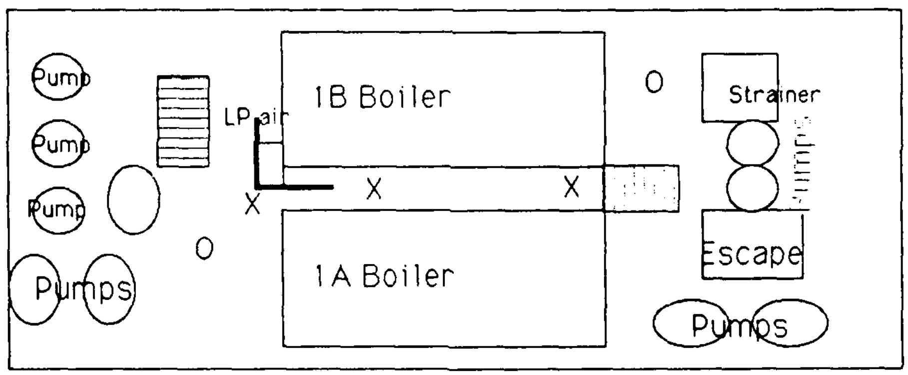
Figure 6a. Graphic depiction of upper (U/L) level of the # 1 Engine Room of the U.S.S. Yarnell.

U.S.S. YARNELL

#1 FIRE ROOM U/L

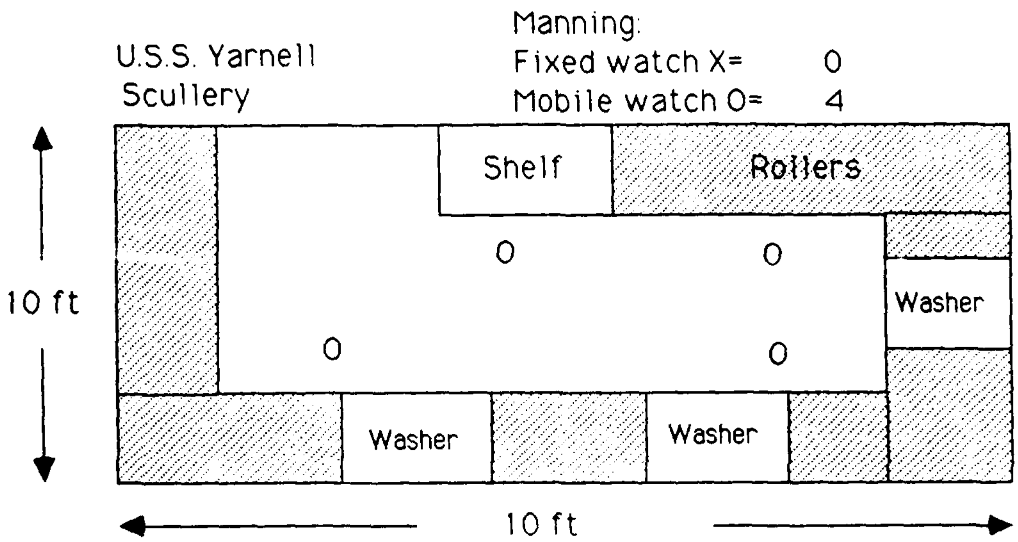


#1 Fire Room L/L



Manning:
Fixed watch X= 4
Mobile watch O= 3

Figure 6b. Graphic depiction of upper (U/L) and lower (L/L) level of the #1 Fire Room of the U.S.S. Yarnell.



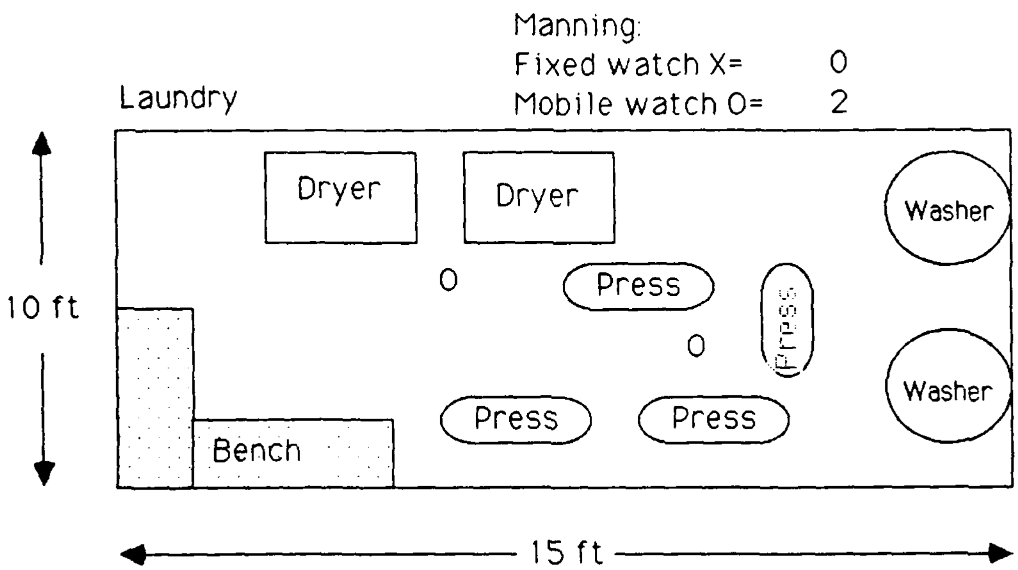


Figure 6c. Graphic depiction of the Scullery and Laundry Room of the U.S.S. Yarnell.

TABLE 1a : Work space data for the U.S.S. Coral Sea.

SPACE	TEMPERATURE (deg.F)	HUMIDITY (%)	ELECTRICITY (VOLTS AC)	LPAC AVAILABILITY
I. ENGINEERING				
ENGINE 1	90-95	95	120	YES
ENGINE 2*	90-95	95	120	YES
ENGINE 3*	90-95	95	120	YES
ENGINE 4*	90-95	95	120	YES
FIRE 1A	95-115	95	120/440	YES
FIRE (2-12)*	95-115	95	120/440	YES
GEN 1*	95-100	95	120/440	YES
GEN 2*	95-100	95	120/440	YES
GEN 3	95-100	95	120/440	YES
GEN 4*	95-100	95	120/440	YES
PUMP 1	100-105	95	120	YES
PUMP 2*	100-105	95	120	YES
PUMP 3*	100-105	95	120	YES
PUMP 4*	100-105	95	120	YES
II. OTHER				
BAKE SHOP	100	95	120	NO
LAUNDRY	110	95	120	YES
AFT SCULLERY	90	95	-	NO
AFT GALLEY	90	85	120	NO

* Specific data not provided, implying similarity of spaces.

TABLE 1b : Air vest requirements for the U.S.S. Coral Sea.

SPACE	FIXED WATCH	SHIFTS	AIR VESTS & HOSES	REGULATORS & FILTERS	TOTAL COST
ENGINEERING					
ENGINE 1	1	3	3	1	
ENGINE 2*	1	3	3	1	
ENGINE 3*	1	3	3	1	
ENGINE 4*	1	3	3	1	
FIRE 1A	3	3	9	1	
FIRE (2-12)*	33	3	99	11	
GEN 1*	1	3	3	1	
GEN 2*	1	3	3	1	
GEN 3	1	3	3	1	
GEN 4*	1	3	3	1	
PUMP 1	1	3	3	1	
PUMP 2*	1	3	3	1	
PUMP 3*	1	3	3	1	
PUMP 4*	1	3	3	1	
TOTAL ENGINEERING					
NORMAL OPS	48		144	24	$67,968
**[GEN QUARTERS	96		144	36	$69,408]
OTHER					
BAKE SHOP	0	1	0	0	
LAUNDRY	3	1	3	1	
AFT SCULLERY	3	3	9	1	
AFT GALLEY	0	3	0	0	
TOTAL OTHER					
NORMAL OPS	6		12	2	$5,664
COMPLETE OUTFIT					
NORMAL OPS	54		156	26	$73,632
**[GEN QUARTERS	102		156	38	$75,072]

---

* Specific data not provided, implying similarity of spaces.

** *Because manning during GQ can double, manning for fixed watch was calculated as* Fixed Watch X 2. Regulators and Filters were adjusted to meet this increased demand. A Regulator & Filter assembly was provided as support for every 3 air vests in a work space.

Note: Additional LPAC requirements are listed in Table 9.

TABLE 1c : Ice vest requirements for the U.S.S. Coral Sea.

SPACE	MOBILE WATCH	SHIFTS	ICE VEST	ICE MACHINES	BATTERY & CHARG SYS	TOTAL COST
ENGINEERING						
ENGINE 1	4	3	12		12	
ENGINE 2*	4	3	12		12	
ENGINE 3*	4	3	12		12	
ENGINE 4*	4	3	12		12	
FIRE 1A	2	3	6		6	
FIRE (2-12)*	22	3	66		66	
GEN 1*	2	3	6		6	
GEN 2*	2	3	6		6	
GEN 3	2	3	6		6	
GEN 4*	2	3	6		6	
PUMP 1	1	3	3		3	
PUMP 2*	1	3	3		3	
PUMP 3*	1	3	3		3	
PUMP 4*	1	3	3		3	
TOTAL ENGINEERING						
NORMAL OPS	52		156	3	156	$113,820
**[GEN QUARTERS	104		156	5	156	$216,220]
OTHER						
BAKE SHOP	3	1	3		3	
LAUNDRY	8	1	8		8	
AFT SCULLERY	1	3	3		3	
AFT GALLEY	12	3	36		36	
TOTAL OTHER						
NORMAL OPS	24		50	2	50	$45,100
COMPLETE OUTFIT						
NORMAL OPS	76		206	4	206	$150,620
**[GEN QUARTERS	128		206	7	206	$261,320]

* Specific data not provided, implying similarity of spaces.
** Because manning during GQ can double, manning for Mobile Watch was calculated as Mobile Watch X 2. Ice machines and Battery Charging Systems were adjusted to meet the increased demands.
Note: Cost of battery/charger system for normal operations = $350 (4 batteries + 3 chargers); for GQ = $900 (12 batteries + 6 chargers)
Note: Because each ice machine can support 20 vests, the number of ice machines for the complete outfit is not necessarily the sum of the Total Other + Total Engineering.

TABLE 2a : Work space data for the U.S.S. Lexington.

SPACE	TEMPERATURE (deg.F)	HUMIDITY (%)	ELECTRICITY (VOLTS AC)	LPAC AVAILABILITY
I. ENGINEERING				
MAIN CONTROL	120	95	120/440	YES
AFT ENGINE*	110	95	120/440	YES
FIRE 1	120	95	120/440	YES
FIRE 2*	120	95	120/440	YES
FIRE 3	120	95	120/440	YES
FIRE 4*	120	95	120/440	YES
FWD AUX	95	85	120/440	YES
AFT AUX*	95	90	120/440	YES
II. OTHER				
LAUNDRY	110	90	120	YES
SCULLERY	95	90	120	NO

* Specific data not provided, implying similarity of spaces.

TABLE 2b: Air vest requirements for the U.S.S. Lexington.

SPACE	FIXED WATCH	SHIFTS	AIR VESTS & HOSES	REGULATORS & FILTERS	TOTAL COST
ENGINEERING					
MAIN CONTROL	4	3	12	2	
AFT ENGINE*	2	3	6	1	
FIRE 1	6	3	18	2	
FIRE 2*	6	3	18	2	
FIRE 3	8	3	24	3	
FIRE 4*	8	3	24	3	
FWD AUX	3	3	9	1	
AFT AUX*	0	3	0	0	
TOTAL ENGINEERING					
NORMAL OPS	37		111	14	$51,852
**[GEN QUARTERS	74		111	27	$53,412]
OTHER					
LAUNDRY	3	1	3	1	
SCULLERY	2	3	6	1	
TOTAL OTHER					
NORMAL OPS	5		9	2	$4,308
COMPLETE OUTFIT					
NORMAL OPS	42		120	16	$56,160
**[GEN QUARTERS	79		120	29	$57,720]

* Specific data not provided, implying similarity of spaces. Also note the difference between the Forward and the Aft Auxiliary rooms. The spaces are very similar, however, in the Aft Auxiliary room there is no fixed watch required and only one mobile watch located in the lower level. The Aft Engine room is also similar to the Main Control, however, there are only two fixed and three mobile watch (one half the manning of Main Control).

** Because manning during GQ can double, manning for fixed watch was calculated as Fixed Watch X 2. Regulators and Filters were adjusted to meet this increased demand. A Regulator & Filter assembly was provided as support for every 3 air vests in a work space.

Note: Additional LPAC requirements are listed in Table 9.

TABLE 2c : Ice vest requirements for the U.S.S. Lexington.

SPACE	MOBILE WATCH	SHIFTS	ICE VEST	ICE MACHINES	BATTERY & CHARG SYS	TOTAL COST
ENGINEERING						
MAIN CONTROL	6	3	18		18	
AFT ENGINE*	3	3	9		9	
FIRE 1	6	3	18		18	
FIRE 2*	6	3	18		18	
FIRE 3	8	3	24		24	
FIRE 4*	8	3	24		24	
FWD AUX	1	3	3		3	
AFT AUX*	1	3	3		3	
TOTAL ENGINEERING						
NORMAL OPS	39		117	2	117	$83,290
**[GEN QUARTERS	78		117	4	117	$164,240]
OTHER						
LAUNDRY	3	1	3		3	
SCULLERY	2	3	6		6	
TOTAL OTHER						
NORMAL OPS	5		9	1	9	$13,430
COMPLETE OUTFIT						
NORMAL OPS	44		126	3	126	$96,720
**[GEN QUARTERS	83		126	4	126	$169,370]

* Specific data not provided, implying similarity of spaces.

** Because manning during GQ can double, manning for Mobile Watch was calculated as Mobile Watch X 2. Ice machines and Battery Charging Systems were adjusted to meet the increased demands.

Note: Cost of battery/charger system for normal operations = $350 (4 batteries + 3 chargers); for GQ = $900 (12 batteries + 6 chargers)

Note: Because each ice machine can support 20 vests, the number of ice machines for the complete outfit is not necessarily the sum of the Total Other + Total Engineering.

TABLE 3a : Work space data for the U.S.S. Lawrence.

SPACE	TEMPERATURE (deg.F)	HUMIDITY (%)	ELECTRICITY (VOLTS AC)	LPAC AVAILABILITY
I. ENGINEERING				
FWD ENG	115	90	120/440	YES
AFT ENG*	115	90	120/440	YES
FWD FIRE	115	90	120/440	YES
AFT FIRE*	115	90	120/440	YES
II. OTHER				
LAUNDRY	115	90	120	YES
SCULLERY	110	90	120	NO

*Specific data not provided, implying similarity of spaces.

TABLE 3b : Air vest requirements for the U.S.S. Lawrence.

SPACE	FIXED WATCH	SHIFTS	AIR VEST & HOSES	REGULATORS & FILTERS	TOTAL COST
ENGINEERING					
FWD ENG	4	2	8	2	
AFT ENG*	4	2	8	2	
FWD FIRE	2	2	4	1	
AFT FIRE*	2	2	4	1	
TOTAL ENGINEERING					
NORMAL OPS	12		24	6	$11,568
**[GEN QUARTERS	24		24	10	$12,048]
OTHER					
LAUNDRY	1	1	1	1	
SCULLERY	1	3	3	1	
TOTAL OTHER					
NORMAL OPS	2		4	2	$2,048
COMPLETE OUTFIT					
NORMAL OPS	14		28	8	$13,616
**[GEN QUARTERS	26		28	12	$14,096]

* Specific data not provided, implying similarity of spaces.
** Because manning can double during GQ, manning for fixed watch was calculated as Fixed Watch X 2. Regulators and Filters were adjusted to meet this increased demand. A Regulator & Filter assembly was provided as support for every 3 air vests in a work space.
Note: Additional LPAC requirements are listed in Table 9.

TABLE 3c : Ice vest requirements for the U.S.S. Lawrence.

SPACE	MOBILE WATCH	SHIFTS	ICE VEST	ICE MACHINES	BATTERY & CHARG SYS	TOTAL COST
ENGINEERING						
FWD ENG	4	2	8		8	
AFT ENG*	4	2	8		8	
FWD FIRE	4	2	8		8	
AFT FIRE*	4	2	8		8	
TOTAL ENGINEERING						
NORMAL OPS	16		32	1	32	$31,340
**[GEN QUARTERS	32		32	2	32	$52,440]
OTHER						
LAUNDRY	0	1	0		0	
SCULLERY	1	3	3		3	
TOTAL OTHER						
NORMAL OPS	1		3	1	3	$10,010
COMPLETE OUTFIT						
NORMAL OPS	17		35	1	35	$33,050
**[GEN QUARTERS	33		35	2	35	$54,150]

* Specific data not provided, implying similarity of spaces.

** Because manning during GQ can double, manning for Mobile Watch was calculated as Mobile Watch X 2. Ice machines and Battery Charging Systems were adjusted to meet the increased demands.

Note: Cost for battery/charger system for normal operations=$500 (6 batteries + 4 chargers) for the engineering spaces and the laundry and $350 (4 batteries + 3 chargers) for the scullery. For GQ, cost for the engineering space $900 (12 batteries + 6 chargers).

Note: Because each ice machine can support 20 vests, the number of ice machines for the complete outfit is not necessarily the sum of the Total Other + Total Engineering.

TABLE 4a : Work space data for the U.S.S. Nashville.

SPACE	TEMPERATURE (deg.F)	HUMIDITY (%)	ELECTRICITY (VOLTS AC)	LPAC AVAILABILITY
I. ENGINEERING				
ENGINE 1	*	*	120/440	YES
ENGINE 2	*	*	120/440	YES
II. OTHER				
LAUNDRY	*	*	120	YES
SCULLERY	*	*	120	NO

* Data were not reported in reference (4)

TABLE 4b : Air vest requirements for the U.S.S. Nashville.

SPACE	FIXED WATCH	SHIFTS	AIR VEST & HOSES	REGULATORS & FILTERS	TOTAL COST
ENGINEERING					
ENGINE 1	7	2	14	3	
ENGINE 2	7	2	14	3	
TOTAL ENGINEERING					
NORMAL OPS	14		28	6	$13,376
**[GEN QUARTERS	28		28	10	$13,856]
OTHER					
LAUNDRY	0	1	0	0	
SCULLERY	0	2	0	0	
TOTAL OTHER					
NORMAL OPS			0	0	NC
COMPLETE OUTFIT					
NORMAL OPS	14		28	6	$13,376
**[GEN QUARTERS	28		28	10	$13,856]

** Because manning can double during GQ, manning for fixed watch was calculated as Fixed Watch X 2. Regulators and Filters were adjusted to meet this increased demand. A Regulator & Filter assembly was provided as support for every 3 air vests in a work space.
Note: Additional LPAC requirements are listed in Table 9.

TABLE 4c : Ice vest requirements for the U.S.S. NASHVILLE

SPACE	MOBILE WATCH	SHIFTS	ICE VEST	ICE MACHINES	BATTERY & CHARG SYS	TOTAL COST
ENGINEERING						
ENGINE 1	5	2	10		10	
ENGINE 2	4	2	8		8	
TOTAL ENGINEERING						
NORMAL OPS	9		18	1	18	$21,260
**[GEN QUARTERS	18		18	1	18	$28,460]
OTHER						
LAUNDRY	3	1	3		3	
SCULLERY	2	2	4		4	
TOTAL OTHER						
NORMAL OPS	5		7	1	7	$13,340
COMPLETE OUTFIT						
NORMAL OPS	14		25	1	25	$26,300
**[GEN QUARTERS	23		25	2	25	$41,800]

** Because manning during GQ can double, manning for Mobile Watch was calculated as Mobile Watch X 2. Ice machines and Battery Charging Systems were adjusted to meet the increased demands.
Note: Cost of battery/charger system for normal operations = $500 (6 batteries + 4 chargers); for GQ = $900 (12 batteries + 6 chargers).
Note: Because each ice machine can support 20 vests, the number of ice machines for the complete outfit is not necessarily the sum of the Total Other + Total Engineering.

TABLE 5a : Work space data for the U.S.S. Mc Cloy.

SPACE	TEMPERATURE (deg.F)	HUMIDITY (%)	ELECTRICITY (VOLTS AC)	LPAC AVAILABILITY
I. ENGINEERING				
FWD ENGINE	120	95	120/440	YES
AFT ENGINE*	120	95	120/440	YES
FWD FIRE	120	95	120/440	YES
AFT FIRE*	120	95	120/440	YES
II. OTHER				
GALLEY	115	95	120	NO
LAUNDRY	120	95	120	YES
SCULLERY	115	95	120	NO

* Specific data not provided, implying similarity of spaces.

TABLE 5b : Air vest requirements for the U.S.S. Mc Cloy.

SPACE	FIXED WATCH	SHIFTS	AIR VESTS & HOSES	REGULATORS & FILTERS	TOTAL COST
ENGINEERING					
FWD ENGINE	4	2	8	2	
AFT ENGINE*	4	2	8	2	
FWD FIRE	4	2	8	2	
AFT FIRE*	4	2	8	2	
TOTAL ENGINEERING					
NORMAL OPS	16		32	8	$15,424
**[GEN QUARTERS	32		32	12	$15,904]
OTHER					
GALLEY	0	2	0		
LAUNDRY	1	1	1	1	
SCULLERY	0	3	0		
TOTAL OTHER	1		1	1	$572
COMPLETE OUTFIT					
NORMAL OPS	17		33	9	$15,996
**[GEN QUARTERS	33		33	13	$16,476]

* Specific data not provided, implying similarity of spaces.
** Because manning can double during GQ, manning for fixed watch was calculated as Fixed Watch X 2. Regulators and Filters were adjusted to meet this increased demand. A Regulator & Filter assembly was provided as support for every 3 air vests in a work space.
Note: Additional LPAC requirements are listed in Table 9.

TABLE 5c : Ice vest requirements for the U.S.S. Mc Cloy

SPACE	MOBILE WATCH	SHIFTS	ICE VEST	ICE MACHINE	BATTERY & CHARG SYS	TOTAL COST
ENGINEERING						
FWD ENGINE	2	2	4		4	
AFT ENGINE*	2	2	4		4	
FWD FIRE	2	2	4		4	
AFT FIRE*	2	2	4		4	
TOTAL ENGINEERING						
NORMAL OPS	8		16	1	16	$19,820
**[GEN QUARTERS	16		16	1	16	$26,220]
OTHER						
GALLEY***	3	2	6		6	
LAUNDRY	0	1	0		0	
SCULLERY	2	3	6		6	
TOTAL OTHER						
NORMAL OPS	5		12	1	12	$16,040
COMPLETE OUTFIT						
NORMAL OPS	13		28	1	28	$27,560
**[GEN QUARTERS	21		28	1	28	$33,960]

* Specific data not provided, implying similarity of spaces.

** Because manning during GQ can double, manning for Mobile Watch was calculated as Mobile Watch X 2. Ice machines and Battery Charging Systems are adjusted to meet the increased demands.

*** According to Figure 5c, there are 4 mobile watches during the day and 2 at night in the galley. For simplicity, we used an average figure of three mobile watches for the calculation.

Note: Cost for battery/charger system for normal operations=$500 (6 batteries + 4 chargers) for the engineering spaces, galley, and laundry and $350 (4 batteries + 3 chargers) for scullery. For GQ, cost for engineering space = $900 (12 batteries + 6 chargers).

Note: Because each ice machine can support 20 vests, the number of ice machines for the complete outfit is not necessarily the sum of the Total Other + Total Engineering.

TABLE 6a : Work space data for the U.S.S. Yarnell.

SPACE	TEMPERATURE (deg.F)	HUMIDITY (%)	ELECTRICITY (VOLTS AC)	LPAC AVAILABILITY
I. ENGINEERING				
ENGINE 1	120	95	120/440	YES/P
ENGINE 2*	120	95	120/440	YES/P
FIRE 1	120	95	120/440	YES/P
FIRE 2*	120	95	120/440	YES/P
II. OTHER				
SCULLERY	120	90	120	NO
LAUNDRY	120	90	120	YES/P

* Specific data not provided, implying similarity of spaces.
NOTE: /P indicates air lines are prioritized. Under General Quarters or emergency conditions air will be provided for control equipment only.

TABLE 6b : Air vest requirements for the U.S.S. Yarnell.

SPACE	FIXED WATCH	SHIFTS	AIR VEST & HOSES	REGULATORS & FILTERS	TOTAL COST
ENGINEERING					
ENGINE 1	1	2	2	1	
ENGINE 2*	1	2	2	1	
FIRE 1	4	2	8	2	
FIRE 2*	4	2	8	2	
TOTAL ENGINEERING					
NORMAL OPS	10		20	6	$9,760
**[GEN QUARTERS	20		20	8	$10,000]
OTHER					
SCULLERY	0	3	0	0	
LAUNDRY	0	1	0	0	
TOTAL OTHER					
NORMAL OPS	0		0	0	N/C
COMPLETE OUTFIT					
NORMAL OPS	10		20	6	$9,760
**[GEN QUARTERS	20		20	8	$10,000]

* Specific data not provided, implying similarity of spaces.
** Because manning can double during GQ, manning for fixed watch was calculated as Fixed Watch X 2. Regulators and Filters were adjusted to meet this increased demand. A Regulator & Filter assembly was provided as support for every 3 air vests in a work space.
Note: Additional LPAC requirements are listed in Table 9.

TABLE 6c : Ice vest requirements for the U.S.S. Yarnell.

SPACE	MOBILE WATCH	SHIFTS	ICE VEST	ICE MACHINES	BATTERY & CHARG SYS	TOTAL COST
ENGINEERING						
ENGINE 1	2	2	4		4	
ENGINE 2*	2	2	4		4	
FIRE 1	3	2	6		6	
FIRE 2*	3	2	6		6	
TOTAL ENGINEERING						
NORMAL OPS	10		20	1	20	$22,700
**[GEN QUARTERS	20		20	1	20	$30,700]
OTHER						
SCULLERY	4	3	12		12	
LAUNDRY	2	1	2		2	
TOTAL OTHER						
NORMAL OPS	6		14	1	14	$16,580
COMPLETE OUTFIT						
NORMAL OPS	16		34	1	34	$30,980
**[GEN QUARTERS	26		34	2	34	$47,280]

* Specific data not provided, implying similarity of spaces.
** Because manning during GQ can double, manning for Mobile Watch was calculated as Mobile Watch X 2. Ice machines and Battery Charging Systems were adjusted to meet the increased demands.
Note: Cost for battery/charger system for normal operations=$500 (6 batteries + 4 chargers) for the engineering spaces and the laundry and $350 (4 batteries + 3 chargers) for the scullery. For GQ, cost for the engineering space = $900 (12 batteries + 6 chargers).
Note: Because each ice machine can support 20 vests, the number of ice machines for the complete outfit is not necessarily the sum of the Total Other + Total Engineering.

TABLE 7 : Unit costs for the Air System (Encon Vortex) and Ice System (ILC Ice Vest).

AIR SYSTEM :

ITEM	COST
VEST	$200.00
VORTEX	$196.00
AIR HOSE(50')	$50.00
BELT	$6.00
TOTAL	$452.00
REGULATOR, FILTER; HARDWARE	$120.00

ICE SYSTEM :

ITEM	COST
VEST	$220.00
BATTERY	$50.00
CHARGER	$50.00
ICE MACHINE	$8,300.00

Note: Ice vest price based on a quantity >25

Note : Battery and charger price based on a quantity >11

TABLE 8 : Summary of cost estimates for three scenarios of outfitting different class ships with air and liquid MCS's. (Note: Per CINCLANTFLT, Emergency Use Only System is for ice vest only).

SHIP	OUTFITTING LEVEL	COST ICE	COST AIR	TOTAL COST
CORAL SEA	EMERGENCY USE ONLY	$18,380		$18,380
CV-43	ENGINEERING			
	NORMAL OPS	$113,820	$67,968	$181,788
	GENERAL QUARTERS	$216,220	$69,408	$285,628
	COMPLETE			
	NORMAL OPS	$150,620	$73,632	$224,252
	GENERAL QUARTERS	$261,320	$75,072	$336,392
LEXINGTON	EMERGENCY USE ONLY	$11,900		$11,900
AVT-16	ENGINEERING			
	NORMAL OPS	$83,290	$51,852	$135,142
	GENERAL QUARTERS	$164,240	$53,412	$217,652
	COMPLETE			
	NORMAL OPS	$96,720	$56,160	$152,880
	GENERAL QUARTERS	$169,370	$57,720	$227,090
LAWRENCE	EMERGENCY USE ONLY	$10,460		$10,460
DDG-2	ENGINEERING			
	NORMAL OPS	$31,340	$11,568	$42,908
	GENERAL QUARTERS	$52,440	$12,048	$64,488
	COMPLETE			
	NORMAL OPS	$33,050	$13,616	$46,666
	GENERAL QUARTERS	$54,150	$14,096	$68,246
NASHVILLE	EMERGENCY USE ONLY	$9,740		$9,740
LPD-13	ENGINEERING			
	NORMAL OPS	$21,260	$13,376	$34,636
	GENERAL QUARTERS	$28,460	$13,856	$42,316
	COMPLETE			
	NORMAL OPS	$26,300	$13,376	$39,676
	GENERAL QUARTERS	$41,800	$13,856	$55,656
MC CLOY	EMERGENCY USE ONLY	$11,180		$11,180
FF-1038	ENGINEERING			
	NORMAL OPS	$19,820	$15,424	$35,244
	GENERAL QUARTERS	$26,220	$15,904	$42,124
	COMPLETE			
	NORMAL OPS	$27,560	$15,996	$43,556
	GENERAL QUARTERS	$33,960	$16,476	$50,436

TABLE 8 (Continued): Summary of cost estimates for three scenarios of outfitting different class ships with air and liquid MCS's.

SHIP	OUTFITTING LEVEL	COST ICE	COST AIR	TOTAL COST
YARNELL	EMERGENCY USE ONLY	$10,460		$10,460
CG-17	ENGINEERING			
	NORMAL OPS	$22,700	$9,760	$32,460
	GENERAL QUARTERS	$30,700	$10,000	$40,700
	COMPLETE			
	NORMAL OPS	$30,980	$9,760	$40,740
	GENERAL QUARTERS	$47,280	$10,000	$57,280

Note: In cases where additional ice making capability is not needed, the cost for the Emergency Use Only system can be reduced by the cost of the ice machine ($8,300).

TABLE 9. Possible compressed air requirements when the Encon Vortex System is worn.

SHIP	# OF AIR VESTS	FLOW REQUIRED (scfm)*
USS Coral Sea		
Engineering, Normal Operations	48	960
Complete, General Quarters	102	2040
USS Lexington		
Engineering, Normal Operations	37	740
Complete, General Quarters	79	1580
USS Lawrence		
Engineering, Normal Operations	12	240
Complete, General Quarters	26	520
USS Nashville		
Engineering, Normal Operations	14	280
Complete, General Quarters	28	560
USS Mc Cloy		
Engineering, Normal Operations	16	320
Complete, General Quarters	33	660
USS Yarnell		
Engineering, Normal Operations	10	200
Complete, General Quarters	20	400

* Since each air vest requires 20 scfm at 80-100 psi, the total flow required is the product of the # of air vests X 20 scfm.